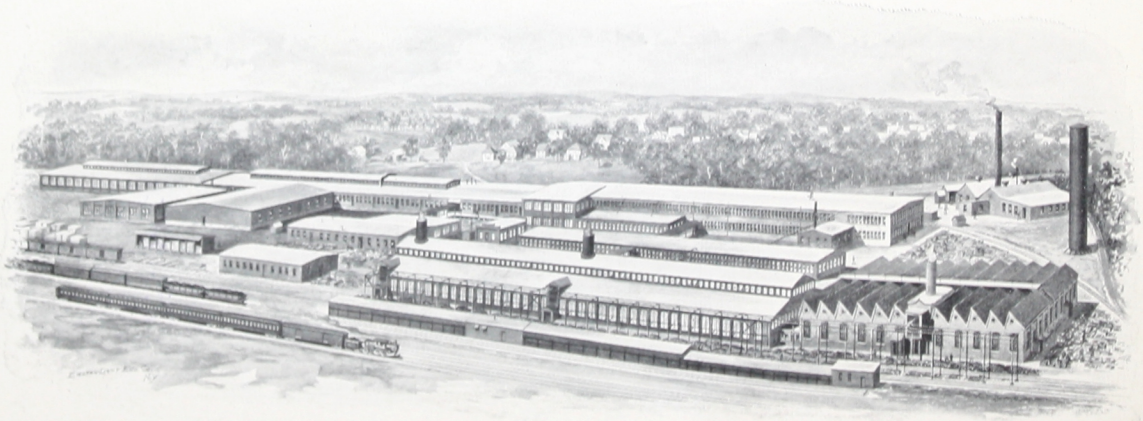
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Second Edition

THE RICHARDSON MANUAL of WARM-AIR HEATING



Our works, as shown above, are so situated as to benefit by two trunk lines, which insures customers prompt shipments and efficient service to all parts of the country.

THE RICHARDSON MANUAL OF WARM-AIR HEATING

A Scientific and Technical Treatise and Manual Based on a definite measure of heat

Endorsed by
ENGINEERS-ARCHITECTS-INSTALLERS

RICHARDSON BOYNTON CO.
1332 Arch Street
Philadelphia, Pa.

RICHARDSON AND BOYNTON CO.

NEW YORK CHICAGO BOSTON PHILADELPHIA

7180 6-1915.

The information and rules contained in this book are for the use of Architects and Prospective Installers of Warm Air Heaters, but their accuracy in general practice can in no way be guaranteed by us.

"Richardson"

[TRADE MARK]
Registered U. S. Patent Office

"Perfect"

[TRADE MARK]
Registered U. S. Patent Office

Copyright 1914
Richardson & Boynton Co.
New York

Definite and Authoritative Measure of Heat

The British Thermal Unit is that amount of heat necessary to raise the temperature of a pound of water from 39 to 40 degrees Fahrenheit, as at that temperature water is at its greatest density. Common practice, however, defines the British Thermal Unit as that amount of heat necessary to raise the temperature of a pound of water one degree Fahrenheit.

This unit of heat measurement in the United States, Canada, and Great Britain is thus termed to distinguish it from the Continental heat unit or Calorie.

The Same Definite Measure of Heat as Applied to Warm Air Heating

is the unit of heat necessary to raise the temperature of one cubic foot of air from zero to 48 degrees Fahrenheit, but common practice has established the rule that one British Thermal Unit is that measure of heat necessary to raise the temperature of one cubic foot of air 55 degrees Fahrenheit. See table on page 98.

Richardson Heat Unit

We have determined that one "Richardson" Heat Unit is the heating value of one square inch of cross-section First Floor pipe area, at 140 degrees Fahrenheit—velocity 240 feet—equal to 110 British thermal units available per hour.

For rules covering the application of the "Richardson" Heat Unit to the design of heating installations, see page 43 and following pages.

A Definite Purpose

The installers of warm air heaters have not been heretofore, supplied with sufficient information regarding rules of measurement, importance of proper installation, or definite capacities of warm air heaters. Our object in issuing this Manual is to place before all those interested

Definite rules of measurement of heat requirements, pipe installation, capacities of various sizes of warm air heaters, and

A Definite Measure of Heat

Quality

IT seems to the Richardson & Boynton Co. as if the time had come for manufacturers to realize the harm that is being done to the Warm Air Heating industry by the manufacture and sale of goods which are entirely speculative, which are very light in weight, and benefit by no modern points of construction whatsoever, and which are manufactured entirely with the idea in view of selling a large quantity of articles.

We believe that the sale of these speculative goods in many sections of the country has led to much dissatisfaction in the minds of the users as to the results of the operation of Warm Air Systems in general. We believe, further, that all those interested in this industry should frown on this common practice.

It has been proven to us, year after year, that it is not only possible to market high grade goods, but profitable, and, further than that, it lends to the upbuilding of this industry.

The Richardson & Boynton Co. have stood almost alone in avoiding the effort towards marketing large numbers of speculative goods. It is true that certain of our lines have been manufactured with the idea of meeting the force of this speculative condition in the market, but we have been very much averse to the general practice.

If a profitable business is to be built up, by an installer of Warm Air Heaters in any section, the heater must have *quality* and *durability*, and be *economical* in the use of fuel. It must be *gas-tight* and also *highly efficient*—and we make a fundamental claim that these qualifications cannot and do not exist in light-weight, speculative goods.

We solicit the aid of installers of Warm Air Heaters to use the utmost care in laying out their heating or ventilating plans in accordance with our rulings, combined with their rules of general practice. If the installer will make every effort toward a good installation he is bound to derive benefit, and the consumer entire satisfaction.

The Richardson Method of Rating the Capacity of Warm Air Heaters

It will be noted, by referring to the ratings of Richardson **"Perfect"** Warm Air Heaters, that we have laid aside the unreliable and faulty idea of rating heaters by means of a table of cubical contents. We are now rating them in accordance with their capacity to supply a certain given number of square inches cross section, warm air pipe area, at certain qualifications. * See page 5.

The square inches of free opening of the warm air pipe to any one room is really what the installer is interested in. The number of square inches of cross section pipe area for any one room can be ascertained by referring to our Rules. Therefore, it seems to us that the proper method is to supply to each room the sufficient number of square inches of cross section pipe area which the room may require to offset heat losses.

* One Richardson Heat Unit

We have determined that one Richardson Heat Unit is the heating value of one square inch of cross-section First Floor pipe area, at 140 degrees Fahrenheit—velocity 240 feet—equal to 110 British thermal units available per hour.

Advantages of Warm Air Heating

The Warm Air Heater is the heart of the heating system. Install one with merit, not of the speculative type, and insist on having it located where it will do the most effective work.

In order to insure entire satisfaction to the house owner, we advise that the next size larger warm air heater than is absolutely necessary be installed.

Large and medium-sized houses can be perfectly heated at all times by means of a Warm Air Heater and, in addition, automatic ventilation provided. In the proper heating of a room by means of a warm air heater, an entire change of air within the room occurs once an hour, and in many instances more than this. By means of the proper size pipe, properly located warm air heater, registers, etc., this abundant warm air supply is not only heating the room, but keeping the atmosphere within the room in a healthy, fresh condition.

This question of automatically ventilating an entire house to the benefit of the occupants is one that deserves considerable thought.

A good Warm Air Heater is very responsive to drafts, and a volume of fresh, warm air can always be quickly supplied which will insure warm dining-room and halls, as well as a warm house generally, and early in the day.

The amount of heat required is easily regulated according to the weather. At many times in the year, particularly in the early Fall or early Spring, just enough heat can be supplied to take off a suggestion of chill, and this, as can be readily understood, is economical to the last degree.

Doctors and scientific experts have all agreed that a constant supply of fresh air is absolutely necessary. By means of the "Richardson System," this demand is met.

Consider two important items of interest to each house owner before the price of the individual heater is considered, namely:

Economy in fuel consumption and maintenance.

Co-operation with the Installer

There is no question but that the best installations in the country today have been made by men who have mastered this class of heating by actual experience and every-day observations, until such judgment on their part has been developed, that definite conclusions have been reached which harmonize with the most careful calculations of the students of technique.

In placing before our clients and customers the "Richardson System" of Heating and Ventilation, we have been careful not to violate the rules of common practice which have been in existence for many years in this industry. We have had the fact constantly before us that the practical installer knows better than anyone else what correct installation means.

Many other methods have been tried, and other systems have been advocated, but in each and every one it necessitates careful measurement of each room, in accordance with that particular system, and unless that particular system is carefully followed, there is no means of arriving at the exact size of the heater.

In placing a definite rated capacity on our various heaters, we have, perhaps, gone a step farther than others in this industry, but we depend upon the installer to use his best efforts to provide for ample size of pipes, proper cold air supply, *proper chimney, etc.* Nothing can be accomplished unless the installer of Warm Air Heaters uses our definite measures of heat in conjunction with his practical knowledge.

We believe that many in the trade have awakened to the fact that there is considerable thought being given to this method of heating. We believe that the simplicity of our method will appeal to the practical man as well as to the technical—but if the tone of the industry is to be raised, it is absolutely necessary that both work together.

Richardson "Perfect" Positive Air Circulating Heat Producer

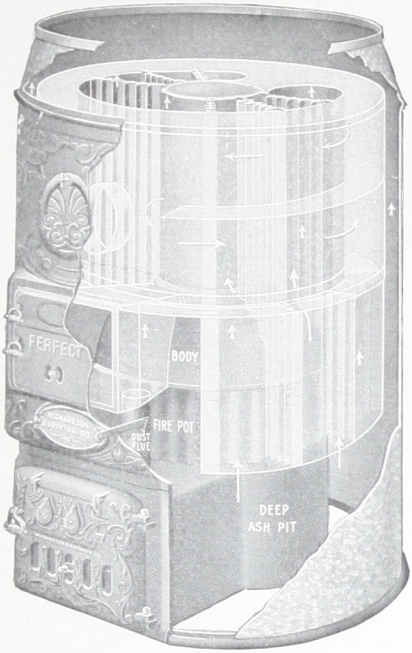
This efficient "Perfect" warm-air heater is a style of construction that is worth attention and examination. Fresh air is circulated through the channels formed by the peculiar construction of this heater, and air thus introduced is quickly heated because it comes in contact with surfaces against which the fire and hot gases come in direct contact. These heating channels create an upward quick circulation of air and the air introduced in the heater is divided and delivered into separate channels, each channel being independent of the others.

Square Feet of Heating Surface in Proportion to Square Feet of Grate

Before those warm air heaters which benefit by modern construction were placed upon the market, the prevailing ratio of square feet of heating surface to one square foot of grate was in the neighborhood of 25 to 1. This construction has been proven to be not only *extravagant* in *fuel*, but extremely low in percentages of *efficiency*. Authorities make no hesitancy in saying that the proportion is entirely too small. The fair proportions, namely—from 40 to 45 sq. ft. of heating surface to 1 sq. ft. of grate—in a Warm Air Heater, can only be found in modern goods which benefit by the proper proportions of surface.

The Richardson & Boynton Co.'s 900 Series "Perfect" Positive Heater shows, in its larger sizes, a proportion of 50 sq. ft. of heating surface to 1 sq. ft. of grate.

These proportions are important. The available heat units in a pound of coal cannot be successfuly used with small proportions of heating surface. This statement holds true of all speculative goods in the market today.



Richardson "Perfect"
Positive Air Circulating Heat Producer

With Steel Radiator—900 Series

See page 21.

Scientific as well as Practical Demonstration of Comparative Value of the "Perfect" Positive 900 Series Warm Air Heaters Measured by the Consumption of Fuel.

In advising the users of Warm Air Heaters to consider our 900 Series "Perfect" Positive Circulator, we not only claim, but we are ready to guarantee that the results obtained are much greater and more positive by this Warm Air Heater than by any other made and that the saving in the consumption of fuel will, in most instances, more than pay for the difference in the cost of the Heater by the end of the second winter season.

This statement is worthy of some consideration, as it is the result of exhaustive tests during the past three winters. Tests have been carried forward in general practice as well as scientific experiment.

The results of these demonstrations have enabled us to place a value in RICHARDSON HEAT UNITS on the various Warm Air Heaters which we guarantee. Please note carefully the following, which is the basis of our argument.

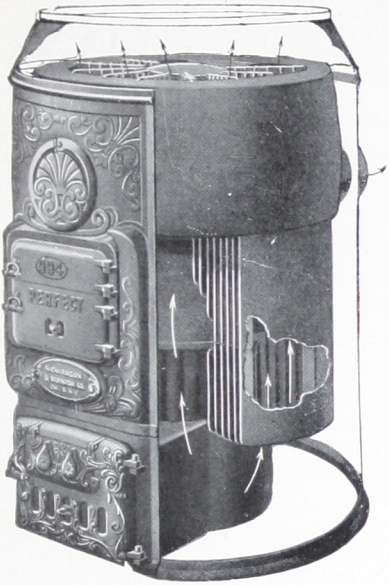
A 210-day exhaustive test on fourteen different types of Warm Air Heaters (each having a 24-inch pot), based on the following conditions:

1. Maximum rate of combustion (on 900 Series Heaters), 6 lbs. of coal per sq. ft. of grate per hour.
2. Temperature maintained at First Floor Register, 140 degrees Fahrenheit.
3. Velocity maintained at First Floor Register, 240 feet.

See tables of capacities for volume, page 21.

Total Coal Consumption Based on the Above		
"Perfect" Positive	"Perfect"	"Perfect"*
900 *Series*	100 *Series*	300 *Series* (*Soft Coal*)
8.37 tons in 210 days	10.5 tons in 210 days	10.94 tons in 210 days

* Anthracite used during test.



Richardson "Perfect" Positive Air Circulating Heat Producer

With Cast-iron Radiator—900 Series

See Page 21

Eleven other warm air heaters of various makes which were tested showed that from 11.1 as high as 12.8 tons in 210 days were used.

It will be noted that we have found the highest efficiency or value in our 900 Series "Perfect" Positive Warm Air Heater. Next to this in value, we have found the 100 Series "Perfect" Warm Air Heater. On a par with the 100 Series, we have found the 300 Series (Soft Coal).

The comparison in consumption of fuel in Richardson Warm Air Heaters (900 Series "Perfect" Positive as compared with the 100 Series and 300 Series) shows conclusively the value and absolute necessity of the following proper proportions of:

First.—Square feet of fire surface to square feet of grate.

Second.—Square feet of flue surface to square feet of grate.

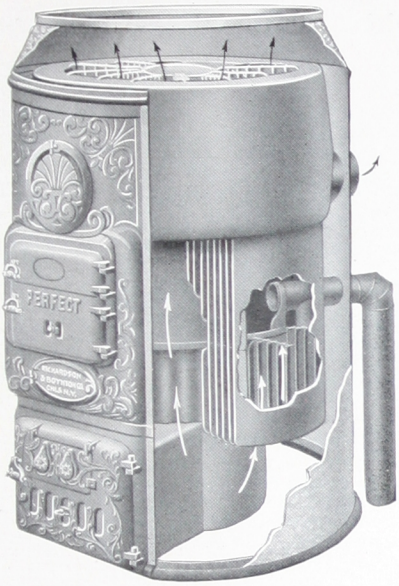
Third.—Square feet of extended surface to square feet of grate.

Note the vast increase in coal consumption by the "Eleven other Warm Air Heaters of Various Makes." If anthracite coal is figured at $7.00 a ton, it will be seen that it pays far better to install a 900 Series "Perfect" Positive Circulator than any other Warm Air Heater manufactured.

Richardson Heaters are manufactured for the use of hard or soft coal, screenings, pea coal, run-of-mine, coke, gas, or wood. You can use fuel at low cost, which may be the most plentiful in your own locality.

Richardson heaters are therefore well adapted to meet any condition and suitable for any section of the country—a fact which will be readily appreciated by dealers in all parts of the United States.

See capacity ratings, pages 21 and 64.



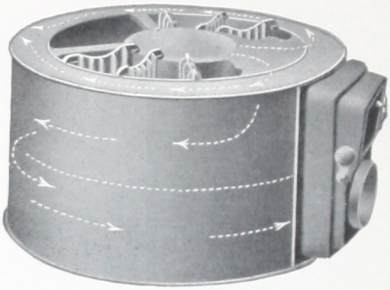
Richardson "Perfect" Positive Air Circulating Heat Producer

For Soft Coal

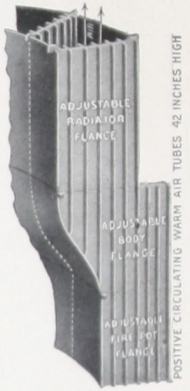
With Cast-iron Radiator—1900 Series

See Page 21

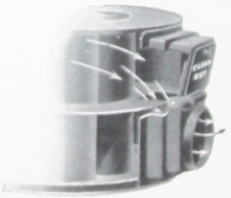
No. 900 Series
Detail of Construction of the
Richardson "Perfect"
Positive Air Circulating Heat Producer



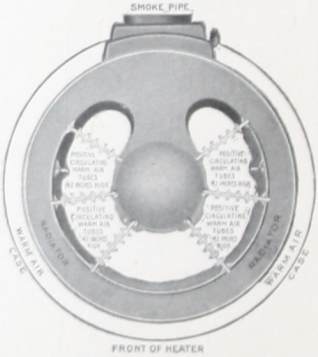
Showing air columns through inside of radiator, also the long smoke travel on both sides, forward and back to smoke collar. All inside and outside surfaces of radiator are directly heated by products of combustion coming in contact with surfaces over which air is passed.



Showingheatedair columns forcing quick air currents to the connected rooms.



Showing direct and indirect damper on back of radiator.



Top view of radiator showing air columns through central air space. This construction produces quick, positive circulation to any desired room or to the whole building.

See Page 21

Proper Grate Construction

In the manufacture of any kind of grates on which fairly good grades of coal are to be burned, it is absolutely essential, in order to obtain the highest degree of efficiency, to have the air passages through the grates in proper proportion to the body of coal thereon. This has been a subject of considerable discussion and much experimentation.

By properly proportioning the free air openings through the grates, that quantity of air is admitted which is necessary for proper combustion of the fuel. This point should be carefully considered when figuring on any coal-burning heater. A proper rate of combustion (see page 61-62-63) cannot be maintained unless the air area through the grates is proportioned properly.

The Effect of Too Much Air

When more air is used than is necessary to effect proper combustion, a great loss of heat units occurs, sometimes as high as 23 per cent. In a pound of high-grade coal, there are only so many heat units available. They may be wasted by reason of badly constructed grates. Too much air through the openings in the grates is a fruitful source of loss of fuel in many cases.

The Effect of Too Little Air

Care must be taken not to curtail the supply of air too much, in which case a great loss will arise from the fact that the gases will not ignite, and so act as a check to combustion.

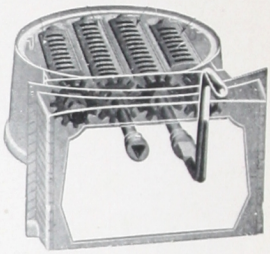
It will be seen by these two items that proper free air openings in the grates is a matter of extreme importance, and that exact adjustment is necessary to produce the best results—too much or too little air causing a great loss.

The result of our experiments has proven to us that properly constructed Warm Air Heaters, operated properly, have available about 9,000 units of heat per lb. of high-grade Anthracite coal.

"Perfect" Grates

"Perfect" Revolving Triangular Ventilated Grates with Cutting Edges, have proved the most perfect operating—most effective—most durable, clinker-clearing grates ever made.

They completely clear the fire from Ashes and Clinkers with very little effort.



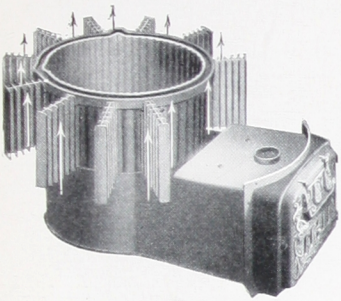
Each edge of the triangle is cast solid; the result is that whichever flat side is uppermost, there is a solid backbone running the entire length of each grate bar. This backbone is braced by webs running to each solid edge. They have proper amount of air space for the complete combustion of fuel and will outlast any other make of triangular grates. **On the end** of each shaking grate bar **is shrunk** a Steel Ring, which is heated red hot and driven on. The result is that the ends of these bars are practically unbreakable.

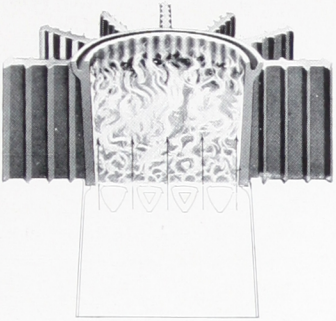
Every horizontal Beam which carries weight, has a solid bottom running the full length. Our Grate Bars have a solid bottom to carry weight so they will not warp.

The grate bar should be always kept flat side up. This position is designated by the opening at the end of the bar, thus; and when left so, the bars are flat and in proper position for use. Only remove shaker, when it is in an upright position. Ash pit must be kept free from ashes, otherwise the grates will be destroyed.

A quick movement of the Shaker Handle right and left, about 3 to 6 inches either way, is sufficient to clear the ashes at any time. In moderate weather shake but little and not often. In colder weather shake twice daily, always leaving grate in flat position as above.

Richardson "Perfect" Pot Construction





The new heavy corrugated firepots, with large adjustable extended heating surfaces, have 450 per cent. more surface than any firepots ever made.

These extended heating surfaces on the firepot add much to the heating capacity of the Heaters, produce large volumes of warm air and save tons of coal.

Our 21-in. Firepots have 3936 sq. ins. heating surface
Other makes have only 928

Our 24-in. Firepots have 4463 sq. ins. heating surface
Other makes have only 1060

Our 26-in. Firepots have 5122 sq. ins. heating surface
Other makes have only 1162

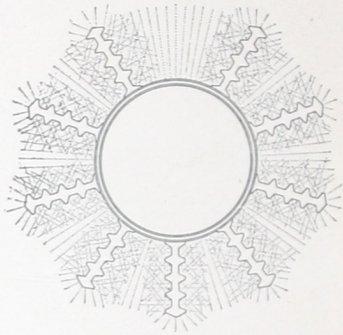
Our 29-in. Firepots have 7587 sq. ins. heating surface
Other makes have only 1326

It is Heating Surface that Counts in all Heating Apparatus

These firepots, with adjustable cast-iron flanges, are used on the Nos. 900, 100, 800 and 300 series "Perfect" heaters.

"Perfect" Flanges

This cut shows the radiation of heat acquired from the extended heating surfaces. These surfaces add 4½ times to surface of firepot — larger quantities of air can thus be heated with same fuel, because there is more heated surface for air to pass over.



The incoming supply of air is brought in close contact with these immense heated surfaces, producing wonderful results.

Dividing the air currents by pot construction, separates the flow of air—presents four times the usual surface for air to pass over—aids circulation—makes a positive, upward, quick air current and thus heats quickly large volumes of air. The result is—a great economy of fuel; heating air at any desired temperature, and controllable at pleasure.

These extended heating surfaces are new. They pull away the heat from the firepot, bringing it out where the cold air comes in direct contact with it, and it is well heated on the commencement of its upward course, before coming in contact with the large heating surfaces of the body and radiator. This means real economy, never before shown in furnace construction.

The Flanges on Pots extend outward from 8 to 12 inches—12 inches high.

The Flanges on Bodies extend outward from 13 to 18 inches.

The Flanges through Radiator are 5 to 12 inches wide.

All small Flanges extend from each side ¾ inches.

Richardson & Boynton Co.

No. 900 Series

"Richardson" Positive Air Circulating Heat Producers

1914 Design

	Size	Price with Cases	Price Less Cases	Diam. Firepot Inches	Square Feet Heating Surface	Diam. Grate Inches	Diam. Radiator Inches	Diam. Cases Inches	Height of Castings Inches	Size Smoke Collar Inches	*Rating Richardson Heat Units	Heat Pipe Capacity Sq. Ins.
	900	**$108.00**	**$ 92.00**	18½	75	16½	31	36	55	7	**312**	**312**
	901	**128.00**	**112.00**	21	105	19	35	40	56	7	**418**	**418**
With Steel	**902**	**164.00**	**146.00**	24	132	22	39½	47	57	8	**560**	**560**
Radiator	**904**	**202.00**	**178.00**	26	160	24	45	53	58½	8	**665**	**665**
	906	**246.00**	**220.00**	29	192	27	49½	58	61	9	**835**	**835**
	908	**320.00**	**284.00**	33	222	31	56½	64	63	10	**1150**	**1150**
	901	**140.00**	**124.00**	21	92	19	34	40	56	8	**375**	**375**
With	**902**	**178.00**	**160.00**	24	127	22	38	47	57	9	**507**	**507**
Cast-iron	**904**	**218.00**	**194.00**	26	153	24	45	53	58½	9	**644**	**644**
Radiator	**906**	**266.00**	**240.00**	29	170	27	47	58	61	10	**814**	**814**
	908	**340.00**	**304.00**	33	194	31	54	64	63	10	**1088**	**1088**
With	**1921**	**150.00**	**134.00**	21	92	19	34	40	56	8	**388**	**388**
Cast-iron	**1922**	**192.00**	**172.00**	24	127	22	38	47	57	9	**474**	**474**
Radiator	**1924**	**228.00**	**204.00**	26	153	24	45	53	58½	9	**598**	**598**
and Hot	**1926**	**278.00**	**252.00**	29	170	27	47	58	61	10	**760**	**760**
Blast for	**1928**	**364.00**	**324.00**	33	194	31	54	64	63	10	**1075**	**1075**
Soft Coal												

* If space is undivided, add 20 per cent.

Note—The above have feed-door frames with opening for pipe coils when ordered.

All of the above fitted with double doors, except No. 900.

A Richardson Heat Unit equals one square inch Warm Air Pipe Area. See pages 5 and 7.

Richardson "Perfect" 100 Series Warm Air Heater

This Heater embodies in its construction many important features necessary to a high grade, warm-air heater. It is furnished with either steel or cast radiator, as desired. The distinctive feature in the construction of these radiators is that their enormous heating surface is positive and benefits by the direct rays of heat from fire.

The Fire Pot is deep and straight, and fitted with "Perfect" Adjustable Heating Flanges which add greatly to the heating power, and furnish large volume of air heated to the proper temperature.

The combustion chamber is especially large, insuring perfect combustion of the gases and the fullest benefit from the coal consumed. The feed chute, which is a part of the combustion chamber, is of generous proportions, and provides for easy firing.

Coil openings are provided in the feed-door frame, through which a coil may be inserted for the purpose of heating water for domestic use, but are only furnished when so stated in the order.

The radiators are large and of the return-flue type, insuring long fire travel and economy in fuel. They are made of high-grade material, are heavy and substantial. A cleanout door is fitted in front of radiator for easy cleaning of same.

Sizes, capacities, etc., page 24.

It is Heating Surface that is Important —if Heating is to be done with Economy of Fuel



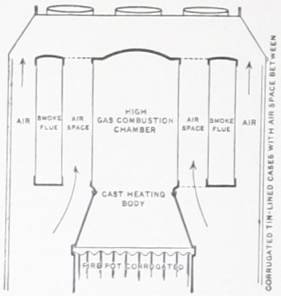
Richardson "Perfect" Warm Air Heaters

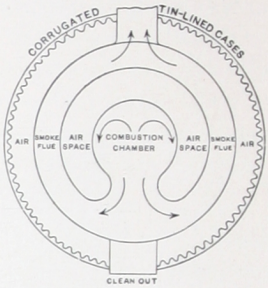
With Straight Fire Pots and Adjustable Cast-iron Flanges—100 Series

See page 24.

No. 100 Series

Richardson "Perfect" Warm Air Heaters





Showing side view of three-wall radiator, having revertible flue smoke passage, with large internal and external heating surfaces, utilizing all products of combustion and producing immense heating power with economy of coal.

Prices, Sizes and Dimensions

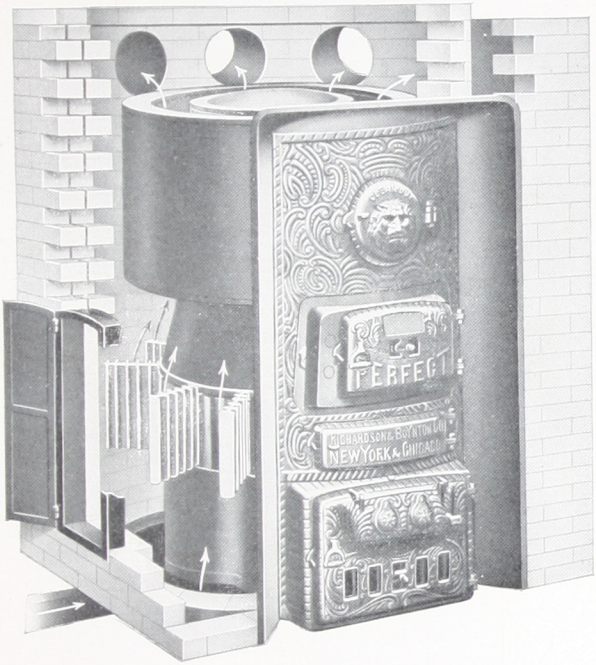
Size	Price with Cases	Price Less Cases	With Cast-iron Radiator Less Cases	With Sheet Iron Radiator in Brick Set Form	Diam. Cases Inches	Diam. Firepot Inches	Diam. Grate Inches	Height Less Cases Inches	**Diam. Radiator Inches**	**Diam. Smoke Pipe Inches**	***Rating Richardson Heat Units**	Heat Pipe Capacity Square inches
131	**$80.00**	**$62.00**			31	16	..	53	**25**	**6**	..	..
135	**96.00**	**78.00**			34	18½	16½	53	**28**	**7**	**274**	**274**
141	**114.00**	**$92.00**	**$98.00**	**$96.00**	39	21	19	54	**32**	**7**	**368**	**368**
144	**142.00**	**118.00**	**126.00**	**122.00**	43	24	22	54½	**36**	**7**	**446**	**446**
148	**172.00**	**144.00**	**156.00**	**148.00**	47	26	24	55	**40**	**8**	**566**	**566**
157	**224.00**	**198.00**	**212.00**	**202.00**	54	29	27	56	**46**	**8**	**716**	**716**
163	**300.00**	**264.00**	**280.00**	**268.00**	61	33	31	57	**51**	**9**	**1013**	**1013**

* If space is undivided, add 20 per cent.

Size 131 does *not* have extension flanges on pot.

Note—All the above excepting Sizes 131, 135 have feed-door frames with opening for pipe coils *when ordered.*

Can be furnished in brick set form if desired.



Richardson "Perfect" 100 Series Warm Air Heaters

Brick Set Form with Steel Radiator

Can be Furnished with Cast-Iron Radiator if Desired

Richardson "Perfect" Heater for Soft Coal

Constructed on scientific principles and long experience as to the requirements of an efficient heater for soft coal.

This Series has been subjected to the most severe tests with many grades and qualities of soft coal, from the best to the cheapest, and the results have never failed to show the same high standard of efficiency which prevails in all **"Richardson"** products.

Oxygen is supplied at a high temperature at the point of combustion, also directly in the middle of fire, through the hot blast attachment shown in the illustration, which insures perfect combustion and saves fully 50 per cent. of the heat usually wasted. All gases are thus consumed and a high rate of efficiency maintained.

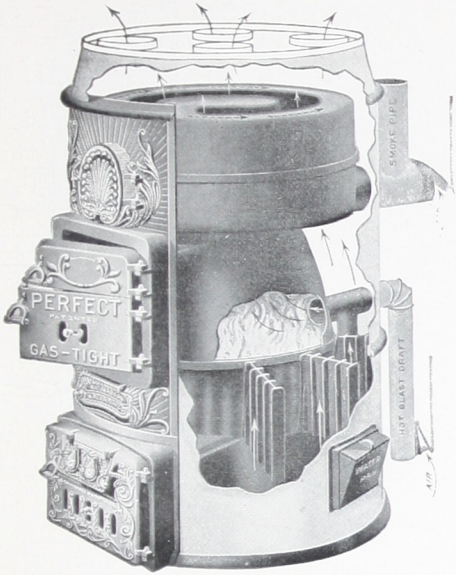
This heater is fitted with **"Perfect"** Straight, Corrugated Firepot, preventing accumulation of ashes on the sides, and with extension flanges, adding many times to the heating surface of the pot, and materially increasing the power of the heater.

Has large return flue, all cast radiator, with long fire travel, and easily cleaned through convenient door in front.

The feed door is large and in two sections, measuring 14 x 14 inches, so that the heater may be conveniently fired.

The ash pit is deep and commodious, allowing ample air space beneath the fire and insuring durability of the grates. An extra large ash pit door facilitates the removal of ashes.

This Heater is heavy, durable and well made, and one which we consider the very best, all cast, soft-coal heater on the market.



Richardson "Perfect" Smoke Consuming Cast Iron Hot Blast for Soft Coal

No. 300 Series

With Large Double-feed Doors

14 x 14 Opening

Size	Price with Cases	Price less Cases	Price in Brick Set Form	Diameter Cases Inches	Diameter Firepot Inches	Diameter Grates Inches	Diameter Radiator Inches	Height Castings, Inches	Smoke Pipe	* Rating Richardson Heat Units	Heat Pipe Capacity Sq. Ins.
349	**$115.50**	**$ 99.00**	**$103.00**	40	21	19	30	56½	8	**358**	**358**
353	**140.00**	**121.00**	**125.00**	44	24	22	34	56½	8	**434**	**434**
357	**166.20**	**145.30**	**149.30**	50	26	24	37	56½	9	**551**	**551**
363	**210.00**	**184.80**	**188.80**	55	29	27	42	57½	9	**697**	**679**
374	**264.00**	**233.10**	**237.10**	61	33	31	51	58½	10	**985**	**985**

* If space is undivided add 20 per cent.
Can be furnished in brick set form if desired.



Richardson "Perfect"
Low Construction Warm Air Heater

This heater has a much greater heating capacity than any other low construction heater manufactured. It delivers the heat where it is wanted. Its low construction gives the best elevation to all warm air pipes, which insures splendid circulation through all of them. It has immense radiating surfaces which produce heat in great volume.

Is fitted for hard coal, soft coal or wood.

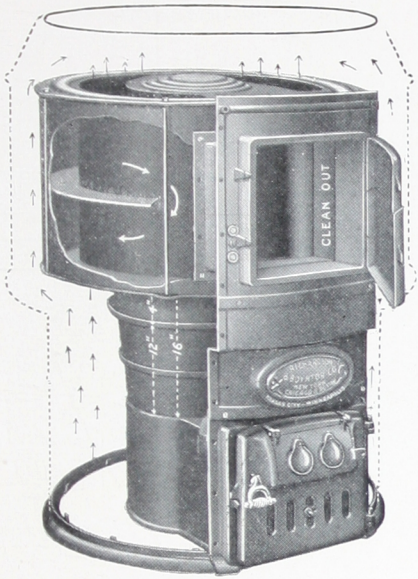
Radiator clean-out plates inside of feed door.

Opening in feed door frame for water pipe connection.

Two-piece firepots, 16 inches deep. Large feed doors, 15×14 inches.

Perfect revolving grates. (See page 18.)

The best heater of its type ever produced.

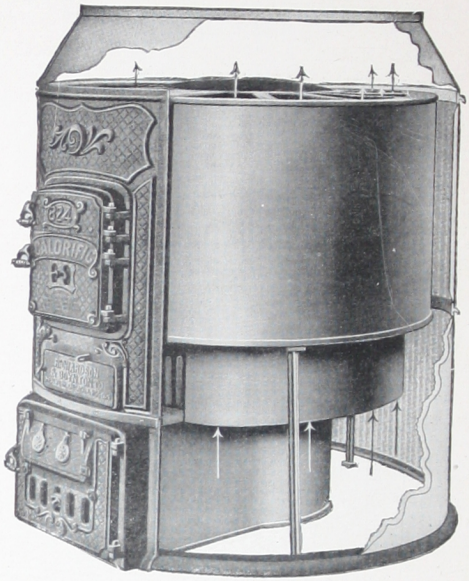


Richardson "Perfect" Low Construction Warm Air Heater

Large Double Feed Doors, 15×14 inches Deep Fire Pots, 16 inches

Size	Price with Casing	Price less Casing	Height of Castings Inches	Diam. Upper Casing, Inches	Diam. Lower Casing, Inches	Diam. Firepot	Diam. Radiator	Height Radiator	Air Opening through Radiator	Smoke Pipe Capacity	*Rating Richardson Heat Units	Heat Pipe Capacity Square Inches
15	**$96.00**	**$78.00**	**48**	41	34	19	36	20	5¼×20	7	**274**	**274**
17	**132.00**	**110.00**	**49**	46	39	22	41	20	5¾×20	8	**363**	**363**
19	**154.00**	**130.00**	**49**	51	44	25	46	20	6¼×20	8	**442**	**442**
21	**190.00**	**165.00**	**50½**	56	49	27½	51	20	6¾×20	9	**560**	**560**

* If space is undivided, add 20 per cent.
Fitted for soft coal if so ordered.

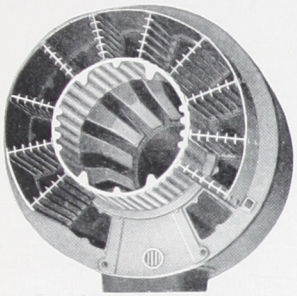


Richardson
Calorific Positive Air Circulator

These heaters produce an abundance of healthful, warm fresh air, furnishing plenty of heat and ventilation. The air currents are divided into as many channels as there are heating columns in each size heater, consequently the heat is distributed directly to far or nearby rooms or halls, independently of each other. The air passes up through the various air columns, which are entirely surrounded by the products of combustion. The hotter the fire the quicker the currents of air are circulated. The heating of near or far rooms is easily controlled to suit the desires of the owner. They insure a pleasant summer-like atmosphere at all times throughout the building, insuring comfort and pleasure.

Can be furnished in brick set form if desired.

Richardson
Calorific Positive Air Circulator



Note one-piece heavy corrugated pot.

Showing Corrugated Fire-pot, with extended surface (heating flanges), which add $4\frac{1}{2}$ times to surface of pot; also shows inside of heater, the formation of air circulation in heating columns around and above the fire. View as looking up from under side of body.



Each of these air columns is an independent heat producer. The immense heating surface in each is exposed to the direct action of the fire, heating large volumes of air.

These air currents have rapid upward circulation directly to rooms, if so desired, producing splendid circulation and keeping uniform heating throughout a building.

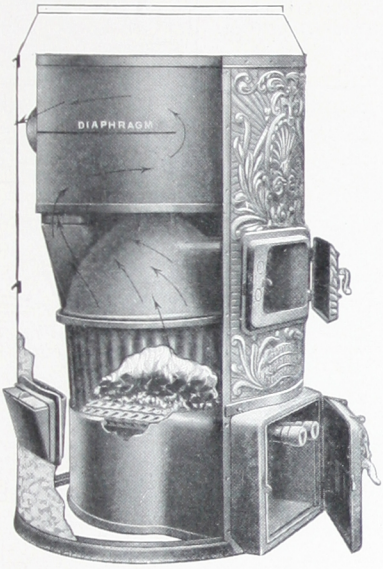
Size	Price With Cases	Price Less Cases	Diam. of Grates Inches	Diameter of Pot	Diameter of Body	Diameter of Cases	Height of Castings	Square Feet of Heating Surface	Number of Warm Air Columns	Capacity of Each Column at Bottom	Smoke Pipe	Rating Richardson Heat Units	Heat Pipe Capacity Square Inches
818	**$182.00**	**$168.00**	18	19½	42½	46	54½	135	9	33	8	**410**	**410**
821	**224.00**	**208.00**	21	22½	48	52	54⅜	150	10	43	8	**558**	**558**
824	**262.00**	**244.00**	24	25½	53½	58	57	175	11	55	9	**731**	**731**
827	**304.00**	**286.00**	27	28½	57½	62½	57	201	12	55	9	**929**	**929**
830	**356.00**	**330.00**	30	31½	63½	68	57	221	12	70	9	**1140**	**1140**

Note—The Calorific series does not have opening for pipe coils on feed-door frames.



Richardson
"Success" Warm Air Heater

Are low in height, have large heating surfaces, and are strong, powerful and durable. The high steel radiators have an exceedingly large amount of heating surface. They are fitted with a diaphragm which insures long fire travel from grate to smoke pipe. Thousands of these heaters are in use, giving universal satisfaction.



Richardson "Success" Warm Air Heater

Size	Price with Cases	Price less Cases	Case Diameter Inches	Pot Diameter Inches	Height of Castings Inches	Diameter Radiator Inches	Diameter Smoke Pipe, Ins.	*Rating Richardson Heat Units	Heat Pipe Capacity Sq. Ins.
2E	$68.00	$56.00	28	16	52	22	6	. .	.
4E	81.00	65.00	32	18½	53	25	6	226	226
61	98.00	82.00	36	21	54	28	7	346	346
81	120.00	100.00	40	24	55½	31	7	420	420
101	148.00	122.00	44	26	58	34½	7	533	533
121	176.00	150.00	50	28½	60	40	8	673	673

* If space is undivided add 20 per cent.

Note—All the above excepting Nos. 2E and 4E have feed-door frames with openings for pipe coils when ordered.

"Progressive" Warm Air Heater

These Heaters produce large volumes of heated air with an economical use of fuel. Owing to the construction of the fire chamber, the combustion chamber and radiator combined which have an enormous amount of heating surface, against which the products of combustion come in direct contact, and over which air passes in a natural manner, large volumes of heated air are produced.

They are constructed with long fire travel through the double return flue radiator, and the various surfaces absorb the heat units from the coal to the fullest possible extent.

They are fitted with the **"Perfect"** triangular three-faced air-circulating grate bars. The best ever made. They will remove ashes and clinkers quickly.

They have large commodious ash pits, for easily removing ashes and adding to the durability of the grates.

They are fitted with a dust flue which, being open when grates are shaken, carries off the dust.

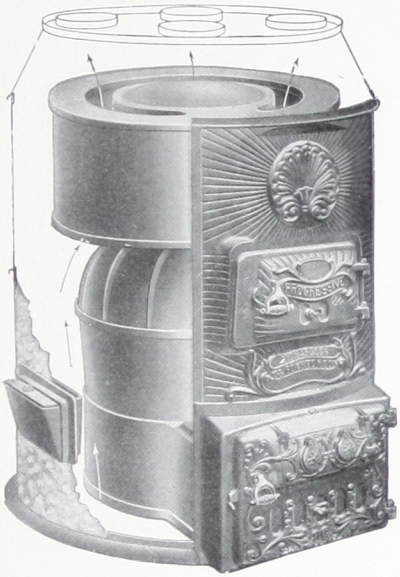
The feed doors are large so that the heater may be easily fired.

The Heaters are fitted with a large, ornamental cast-iron front, having a clean-out opening in the top, making the cleaning of the radiator easily accomplished.

They are fitted with a patent regulating check damper for controlling the chimney draft, which also aids combustion. This damper regulates the fire so that much or little heat can be had, according to the outside temperature.

There are thousands of these heaters giving perfect satisfaction.

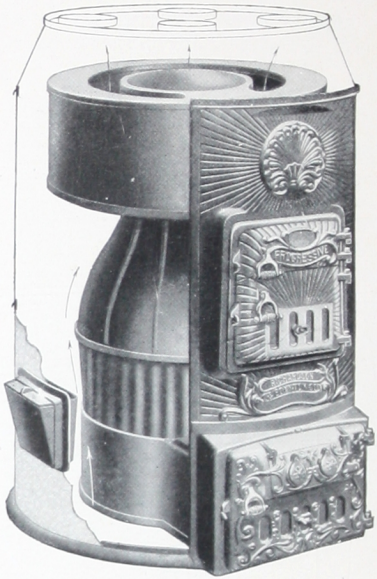
Detail, capacities, etc., page 38.



Richardson
"Progressive" Warm Air Heaters

With Steel or Cast-iron Radiators—1000 Series

See page 38

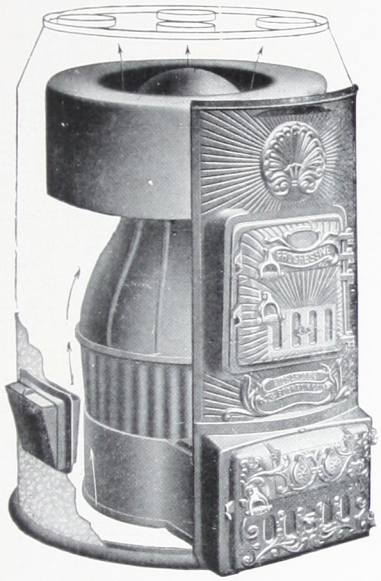


Richardson
"Progressive" Warm Air Heater

With Steel Radiator—4000 Series
With Large Doors for Wood or Coal

When wood is to be used, perforated cast-iron plates can be made specially to place on these grates. They are easily put in position or taken out, according to the wishes of the user.

Detail, capacities, etc., page 38.



Richardson
"Progressive" Warm Air Heater

With Cast-iron Radiator—4000 Series
With Large Doors for Wood or Coal

The construction is new, and has features never heretofore adopted in a heater. It has an unprecedented amount of actual heating surface against which the products of combustion come in direct contact and over which the air passes, thus heating large quantities of fresh air with great economy.

Detail, capacities, etc., page 38.

Progressive Series

	Size	Price with Cases	Price less Cases	Diameter Cases, Inches	Diameter Pot, Inches	Height of Casting, Inches	Smoke Pipe	*Rating Richardson Heat Units	Heat Pipe Capacity Sq. Ins.
	1028	$58.00	$48.00	28	16	45	6		
Steel	1032	70.00	58.00	32	18½	46	6		
Radiator,	†1036	82.00	68.00	36	21	47	7	273	273
Single	†1040	96.00	80.00	40	24	48	7	401	401
Door	†1044	124.00	106.00	44	26	49	7	508	508
	†1050	150.00	130.00	50	29	52	8	576	576
	1032	76.00	64.00	32	18½	46	8		
Cast-iron	†1036	88.00	74.00	36	21	47	8	273	273
Radiator,	†1040	104.00	88.00	40	24	48	8	401	401
Single Door	†1044	136.00	118.00	44	26	49	8	508	508
	†1050	166.00	146.00	50	29	52	9	576	576
	4028	62.00	52.00	28	16	48½	6		
Steel	4032	75.00	63.00	32	18½	49	6		
Radiator,	4036	90.00	76.00	36	21	51	7	273	273
Double	4040	104.00	88.00	40	24	52	7	401	401
Doors	4044	134.00	116.00	44	26	53	7	508	508
	4050	160.00	140.00	50	29	56	8	576	576
Cast-iron	4032	81.00	69.00	32	18½	49	8		
Radiator,	4036	96.00	82.00	36	21	51	8	273	273
Double	4040	112.00	96.00	40	24	52	8	401	401
Doors	4044	146.00	128.00	44	26	53	8	508	508
	4050	178.00	158.00	50	29	56	9	576	276

SEE REVISED PRICES
SEE REVISED PRICES
SEE REVISED PRICES
SEE REVISED PRICES

* For undivided space add 20 per cent.

† Can be furnished in brick set form if desired.

Note—Sizes 32 to 50-inch have feed-door frames with opening for pipe coils when ordered.

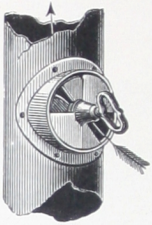


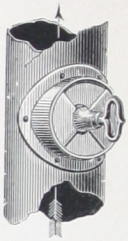
"Perfect" Heaters as Set Up in Battery Form

Are double Heaters, arranged in portable form, with practically one heating chamber. They are particularly recommended for heating large buildings, dwellings, churches, etc., where a single heating plant is desired. They can be used independently or together, according to the weather. They have great heating power, are economical and satisfactory in every way.

Heater Smoke-Pipe Dampers for Hard and Soft Coal

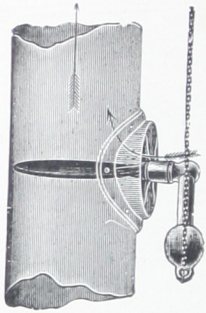
Partly Closed





Open

Style No. 1, Patent Dampers



Style No. 2
Showing Damper inside of Pipe—Draft is Closed and Checked

Dampers are little less in diameter than smoke pipe, allowing always a vent for gases.

When smoke draft is checked, the damper partially closes the smoke pipe and allows for an inlet of air through the register wheel openings.

Style No. 2, weighted patent damper with dial, chains, weights and pulleys, for operating from room above heater.

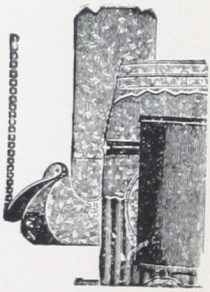
Style No. 3, end lift, damper with dial, chains, weights and pulleys, for soft coal use.

Style No. 4, same as No. 3, only with extra solid damper for back pipe.

Style No. 5, same as No. 2, but with horseshoe plate instead of dial and weights.

Style No. 6, same as No. 3, but with horseshoe plate instead of dial and weights.

Style No. 7, for hot blast soft coal heaters, with cast back pipe and end lift damper, cast thimble, dial and weights.



Style No. 3

Gas Rings

The following Richardson Warm Air Heaters can be furnished with Gas Rings when desired:

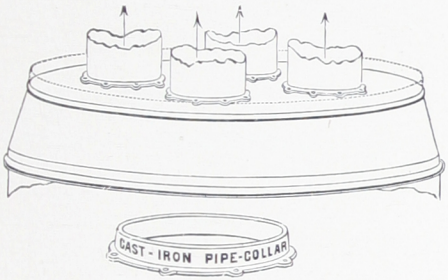
Nos. 901, 902, 904, 906 **"Perfect"** Positive Circulator.

Nos. 141, 144, 148, 157 **"Perfect"** 100 Series.

Nos. 61, 81, 101, 121 **"Success"** Series.

Nos. 1036, 1040, 1044, 1050, 4036, 4040, 4044, 4050 **"Progressive"** Series.

Warm Air Pipe Collars



The above cut shows the style of bonnets sometimes used with heaters when casings are ordered by the trade.

These bonnets allow for pipes to be taken off the top, which will permit a quick flow of warm air.

With pipe connections made in this style, the labor, etc., will cost less than with side connections on high bonnets.

Elbows should all be at the same level, on top—otherwise highest elbows and pipes will take most of the warm air, to the detriment of the other pipes. If dealers want high bonnets for side connections to meet special conditions, please designate the same in ordering.

Warm-air pipe cast-iron collars can be furnished when ordered. Much labor, time and expense will be saved to the dealer by using them.

To Determine Size

"Perfect" Fresh Air Heaters

are rated according to the maximum area of warm air piping in square inches that can be supplied by the heater, based on temperature of 140 degrees and a velocity of 240 feet per minute at the first floor register, maintaining a rate of combustion of six pounds of coal per square foot of grate per hour, outside temperature being zero.

Rated capacities on warm air heaters must carry definite qualifications in order to insure the installer a temperature and velocity on which he can depend. **See pages 5 and 7.**

A simple rule of practice for arriving at the total number of square inch pipe capacity necessary for a building, based on the above qualifications, is as follows:

The total of the area or capacity of the pipes taken off the heater will indicate the size of heater to be used. See rated capacities of each type of furnace.

Example

A house having eight rooms requires the following size pipes:

1—10 inch	equal	78	inches	}	Richardson Heat Units. See Above.
5— 9 "	"	315	"		
2— 8 "	"	100	"		

Total area of pipes 493 inches

A Heater having a rating of at least 500 sq. in. should be used.

For reference the following table will be found useful:

Diameter of round pipes.	Area of pipes in sq. inches.	Sizes of registers to be used with these pipes.
8	50	8 x 12
9	63	10 x 12
10	78	10 x 14
12	113	12 x 16
14	154	14 x 20
16	201	18 x 20
18	254	20 x 22
20	314	22 x 24

Foreword

We urge installers, architects and builders to give a little of their time to the suggestions and rules which many years of experience and exhaustive tests have proven to be exact.

If the information contained herein is accepted in the spirit in which it is given, it will be of vast help to the installer and of great benefit to those interested in Warm Air Heating as an industry; and, further, will prove to be a safe and sanitary method of heating and ventilating.

The information, rules, and data given have been compiled with great care from standard authorities, and will prove of great service if used in connection with practical experience.

Richardson Heat Unit

A Definite Measure of Heat

We have determined that one RICHARDSON HEAT UNIT is the heating value of one square inch of cross-section First Floor pipe area, at 140 degrees Fahrenheit—velocity 240 feet—equal to 110 British thermal units available per hour.

Velocity of warm air rising to the First Floor rooms being 240 ft. per minute, or 14,400 ft. per hour, the number of cubic feet of warm air delivered per hour by one square foot of cross-section pipe area to First Floor register will be 14,400, and the number of cubic feet of warm air delivered per square inch of cross-section First Floor pipe area will be $100 = \frac{14400}{144}$.

The available heat in one cubic foot of warm air in cooling from 140 degrees to 70 degrees is 1.1 British thermal unit. **Therefore,** the available heat per square inch of cross-section pipe area to the First Floor is 1.1×100, or 110 British thermal units.

We have adopted this as the value of one Richardson Heat Unit.

This unit of heat is one which has been used unconsciously by installers of Warm Air heating for many years, for the reason that practical installations are made in accordance with the *pipe size* required

for a certain room, each pipe so required having a certain square inch cross-section capacity at First Floor register. *This square inch capacity, as stated before, we designate as a Richardson Heat Unit.*

Important

Richardson Rule No. 1 for determining the heat requirements of buildings in Richardson Heat Units:

In figuring the heat requirements of any given room in Richardson Heat Units, the following rule, which is easily understood and simple to work out, is recommended as one which has given general satisfaction.

Richardson Rule No. 1

Find the total square feet of glass surface in windows and outside doors, taking the full opening measurements and counting outside doors as all glass (see page 105), then measure the surface in exposed outside wall (see page 104), from which subtract the glass surface; reduce the wall surface to equivalent glass surface by dividing the net amount by:

10	if wall is	8	to 10	inches	thick
15	"	12	" 26	"	"
20	"	26	" 38	"	"

To this result add the glass exposure; then, as one square foot of glass surface cools 75 cubic feet of air per hour, multiply the total glass equivalent by 75 (see page 106), which gives the total cubic feet of air to be heated to offset the loss from glass and wall exposure. This total added to the cubical contents (see pages 107–112) gives the amount of air to be heated.

For a temperature of 70 degrees Fahrenheit in zero weather multiply the amount of air to be heated by .0092*, and the result will be the heat requirements in Richardson Heat Units. For each degree below zero for which the heating is to be required, add 1 per cent. to the heat requirements.

* See page 45 for formula.

Example.—What are the heat requirements in Richardson Heat Units of a room 12×18×9 with 4 windows, 3 ft.×5½ ft. each, with 2 outside walls 10 ins. thick—heating required for 10 degrees below zero.

Square feet of glass surface.....	$3\times5\frac{1}{2}\times 4=$	66
" " outside wall surface.....	$(12+18)\times 9=$	270
Net exposed wall surface.....	270—66 =	204
Equivalent glass surface in wall exposure.....	204÷10 =	20
Amount of air cooled by glass and wall surface.....	$(20+66)\times75=$	6450
Cubical contents of room.....	=	1944
Total cubic feet of air to be heated	=	8394
Heat requirements in Richardson Heat Units for zero weather..	$8394\times .0092^*=$	77
Heat requirements for 10 degrees below zero.....	77+8 =	85

* The coefficient or factor .0092 which we advise using, as per Rule No. 1, is derived from the following formula (Hoffman).

$$\text{H. S.} = \frac{\text{H}\times55\times144}{60\times4\times3600} = .0092\ \text{H.}$$

The above formula H. S. = Area of heat stack in sq. in.

H. = Heat loss from room in British thermal units per hour.

55 = Number of degrees through which one cubic foot of air can be heated by one British thermal unit.

144 = Number of sq. ins. in 1 sq. ft.

60 = Average difference in temperature between air leaving register and room temperature.

4 = Average velocity in feet per second of air in heat stack to first floor rooms.

3600 = Number of seconds in 1 hour.

Richardson Rule No. 2

For those who desire to base their calculations on the most recent information as to the heat losses from buildings, we give the following tables, together with Prof. Carpenter's Rule which is based thereon and our adaptation of it to the "Richardson" System of Warm Air Heating.

The Heat loss in B. t. u. per Hour per Square Foot of Surface per Degree Difference in Temperature for the ordinary types of building construction is given below.

Brick Walls

Thickness Inches	Plain	Plastered One Side	Furred and Plastered	Air Space and Plastered
4	0.52	0.50		
8½	0.37	0.36	0.28	0.25
13	0.29	0.28	0.23	0.21
17½	0.25	0.24	0.20	0.19
22	0.22	0.21	0.18	0.16
26½	0.19	0.18	0.16	0.14

If walls are of concrete, add 20 per cent. to the above values.

For the walls of frame buildings of the indicated outside construction, and lath and plaster inside:

Clapboards, 7/16" thick	0.44
Same with paper lining	0.31
Same with ¾" sheathing	0.28
Same with paper and ¾" sheathing	0.23

For the following indicated types of walls:

Thickness of Board, Inches	Pine Board	Double Board Paper Between	Board and Sheet Iron	Board and Corrugated Iron
½	0.77	0.32	0.50	0.45
1	0.51	0.24	0.40	0.36
1½	0.43	0.19	0.33	0.30
2	0.35	0.16	0.28	0.26
2½	0.30	0.14	0.25	0.23

For the following indicated types of floor surfaces:

Single wooden floor, no plaster under joists	0.45
Same, lath and plaster under joists	0.26
Double wooden floor, no plaster under joists	0.31
Same, lath and plaster under joists	0.18
Concrete floors—same as concrete walls.	

For the following indicated types of floors laid directly on the ground:

Cement or tile, no wood floor above	0.31
Same, wood floor above	0.10
Dirt floor	0.20
Single wood floor, laid near ground	0.10

For the following indicated types of roof construction:

Sheet iron	1.20
Corrugated iron	1.50
Slate on wood frame	0.85
Slate on 1" boards	0.43
Paper, tar and gravel on 2" boards	0.26
Patent tar, gravel and paper	0.30
Tiling 1" thick and less	0.80
2" concrete, tar and gravel on 6" hollow tile	0.35
2" concrete and cinderfill	0.80
4" " " "	0.60
6" " " "	0.54

For the following indicated types of glass surface and doors:

Single windows	1.09
Double "	0.46
Single skylight	1.16
Double "	0.48
Pine doors 1"	0.41
" " $1\frac{1}{2}$"	0.32
" " 2"	0.27

The above figures when multiplied by the area of a surface and the difference in temperature between the air inside and the air outside the surface will give the total heat loss from the surface per hour. The temperature of an unheated space beneath a floor or above a ceiling should be taken as a mean between the indoor and outdoor temperature, and where floors are laid on the ground, the temperature of the ground should be assumed at 30 degrees to 50 degrees Fahrenheit.

Besides the above heat losses, the air entering the building from outside by infiltration or through the opening of doors and windows has to be heated from the outdoor temperature to the room temperature. One B. t. u. will heat 55 cubic feet of air at 70 degrees through 1 degree Fahrenheit. Therefore, if the cubic contents of the building be represented by C, the number of changes of air per hour by n, the indoor temperature by t_r, and the outdoor temperature by t_o, the heat required to offset these leakage losses will be as follows:

$$H_a = \frac{(t_r - t_o)nC}{55}$$

Prof. Carpenter deduces from all the above data that the constant, for single glass, may be taken as 1, and the constant for walls in general may be taken as .25. This makes the total heat loss per hour in B. t. u.,

$$H = (t_r - t_o)\ (G + \tfrac{1}{4}W + \frac{nC}{55})$$

which is known as Carpenter's rule.

We have adopted as our unit the "Richardson" Heat Unit equal to 110 B. t. u. available per hour. Converting the above formula to Richardson Heat Units, and taking $(t_r - t_o) = 70$, we have

$$H_1 = .64\ (G + \tfrac{1}{4}W + \frac{nC}{55})$$

or $H_1 = .64\ (G + .25W + .02nC)$

as the Richardson Rule No. 2. Stated in words, the heat loss in "Richardson" Heat Units per hour is equal to .64 of the sum of the exposed glass surface plus .25 of the exposed wall surface plus .02 of the product obtained by multiplying the cubic contents by the number of air changes per hour. In applying this rule, double windows, double skylights, and exposed doors may be taken as one-half the value of exposed glass; and floors over unheated spaces, or laid directly on the ground, and ceilings under unheated spaces may be taken as one-half the value of exposed wall surface.

Size of Warm Air Heater

After the heat requirements of every room have been determined in "Richardson" Heat Units by the rules given, add the requirements of all the rooms. Select a warm air heater with a rating in "Richardson" Heat Units equal to this latter result, or if the required rating falls between two of the ratings shown in the list, select the larger heater of the two.

The following allowances for various exposures have been found satisfactory in general practice:

For West and Northwest exposures, figured as outside or glass surface, add 10 per cent.; for the East, nothing; for the South, deduct 10 per cent. In the Western and Northwestern sections of the United States, it is the practice to add 10 per cent. for West and Northwest exposures, but to make no deductions for South and East exposures.

Under general conditions this rule will give satisfactory results. It allows for only one change of air per hour. If special ventilation is required, increase the cubical contents as many times as it is necessary to change the air; but the application of the rule remains the same.

Hoffman advises, for the heating of buildings, the following changes per hour:

Halls	3 changes
Sitting rooms and rooms on 1st Floor	2 "
Sleeping rooms and rooms on 2d Floor	1 "
Stores, 1st Floor	2 –3 "
" 2d Floor	1½–2 "
Offices, 1st Floor	2 –2½ "
" 2d Floor	1½–2 "
Churches and public assembly rooms	¾–2 "
Large rooms with small exposure	½–1 "

Size of Heater Figured by Rules of General Average and Practice

If the pipe sizes have been determined directly from Table 2 (Page 55), or in any other way that the experience of the contractor may show to be satisfactory, proceed as follows in selecting the proper size of warm air heater:

Add together the combined area in square inches of the first floor pipes.

Add to this 1.3 times the combined area of the second floor pipes.

Add, again, 1.6 times the combined area of the third floor pipes.

"Richardson" rule gives the total heat requirements of the room in "Richardson" Heat Units; and judgment must be used in increasing the number of "Richardson" Heat Units in the rooms on the cold side, exposed to the North and West, and reducing the number of "Richardson" Heat Units on the warm side (see "Western practice," preceding page); also making allowance for poorly constructed buildings, loose-fitting windows, etc.

Air Recirculating System

In the Western and Northwestern sections of the country, where average winters are very cold and it is more desirable to furnish air to the heater from within the house, allowance should be made in figuring the size of warm-air pipes and returns to the heater, as well as the size heater required, for the conditions which maintain in such a system.

It may be safely stated that the air velocities in a recirculating system will be no less than where the air is taken from outdoors. While the temperature difference between the air entering and leaving the

heater is less with a recirculating system, the resistance to the flow of air is also less, so that the velocities will be practically the same in both systems. The heat in the warm air, which is available for heating is only that which it gives up in cooling from the register temperature to the room temperature, so that the same number of cubic feet of air would be required per hour with indoor circulation as with outdoor air supply if the heat losses were the same with both systems. But the heat losses are much greater with the recirculating system owing to the greatly increased infiltration of air into the building. This amounts in some cases, especially where the return air is taken from a single large register on the first floor, to as much as 50 per cent. more than the heat losses as figured in the ordinary manner. With separate return ducts from each room uniting in a main return duct in the cellar, this excess air loss is much less, though still greater than in an outdoor air supply system. These extra heat losses must be provided for by allowing for more than the usual number of air changes per hour.

One "Richardson" Heat Unit of heater capacity will have twice the value in offsetting heat losses from a building with a recirculating system as with an outdoor air supply system. Therefore, if the heat calculation were the only thing to be considered, a heater having a rated capacity in "Richardson" Heat Units equal to one-half the total heat losses would be sufficiently large, but such a heater would not have a cross-sectional area through the air flues sufficiently large. This area should not be less in any case than the combined area of all the warm air pipes. This point must not be overlooked in selecting a heater for a recirculating system.

Pipe Sizes

After the heat requirements in Richardson Heat Units have been determined by means of any of the rules given, the proper pipe size may be ascertained from Table I, given below:

TABLE I

(All Measurements in Inches)

Diameter of Round Pipe	Area of Pipe Sq. Ins.	Size Flat Riser Pipe	Size Side Wall Register	Size Round Floor Register	Size Rectangular Floor Register	Capacity in Richardson Heat Units		
						1st Floor Rooms	2nd Floor Rooms	3rd Floor Rooms
8	50	3½×14	8×12	12	8×12	50	65	80
9	64	4×16	10×12	14	10×12	64	83	102
10	78	4×20	12×12	14	10×16	78	101	125
11	95	6×16	12×15	16	12×15	95	124	152
12	113	6×19	14×15	18	12×20	113	147	181
13	132	6×22	14×18	18	14×18	132	172	211
14	154	8×19	16×18	20	14×22	154	200	246
15	176	8×22	16×20	24	16×20	176	229	282
16	201	8×25	18×20	24	16×24	201	261	322
17	227	10×23	18×24	24	18×24	227	295	363
18	254	10×26	20×24	24	18×27	254	330	406
19	283	12×24	20×26	28	20×26	283	368	453
20	314	12×26	22×26	28	20×30	314	408	502
21	346	12×29	24×27	30	22×30	346	450	553
22	380	14×27	24×30	30	24×30	380	494	608
23	415	14×30	27×27	30	24×32	415	539	664
24	452	14×32	28×28	36	24×36	452	587	723

(See Page 53, Table of Free Air Opening of Registers.)

The proper size registers to be used for any given number of Richardson Heat Units or for any corresponding pipe size, may be determined by referring to Table I, Page 52.

The velocity of warm air carried to rooms on upper floors is greater than the velocity at first floor register, and for that reason, it is apt to cause unpleasant drafts if register faces are used smaller than is proper for the delivery of that increased velocity.

It is good practice to select a register for a room on the upper floors as though it were a first floor register, running the riser pipe to a register box enlarged sufficiently to take this size register.

On account of this increasing velocity on the upper floors of a residence, smaller pipes can be used than those to the first floor, but the necessary free air opening into the upper rooms must not be overlooked.

Registers

Inasmuch as the heating requirements of any one room demand a certain free air opening, or pipe area in square inches, we deem it wise to print below a table of average sizes of stock registers, of the plain lattice pattern, showing free air opening as guaranteed by the TUTTLE & BAILEY MFG. CO. of New York, and the HART & COOLEY COMPANY, of New Britain, Conn.

We advise, in figuring **other** sizes, that our readers figure on 50 to 55 per cent. of the total square inches of register face in allowing for free air opening for any one pipe.

Round Pipe Inches.	Cross Section Square Inches.	Regular Sizes Register—Floor and Plain Side Wall.	Free Air Opening Square Inches.	Base Board 1st Floor only. Square Inches.	Free Air Opening Square Inches.	Base Board 2d and 3d Floors, Square Inches.	Free Air Opening.
8	50.27	8×12	52.90	7×12	53.20	8×10	49.50
9	63.61	10×12	66.47	8×13	64.40	8×12	59.65
10	78.54	12×14	83.03	10×12	75.00	9×12	66.16
11	95.03	12×15	89.04	10×14	87.71		
12	113.09	14×16	111.07	12×14	105.51		
13	132.73	14×18	125.10				
14	153.93	16×20	172.00				
15	176.71	18×20	193.85				
16	201.06	20×20	215.70				

Richardson Rule of Average for Proportioning Square Inches of Heat Pipe Areas

An easy method of figuring heat requirements by Richardson Rule of Average will give satisfactory results if used in connection with practical experience, although if accurate results are desired, the heat requirements should be figured in connection with glass and wall surfaces, etc., in accordance with Rules, pages 44-48.

Allow one Richardson Heat Unit, or one square inch of cross-section First Floor pipe area for the amount of cubical space shown in the various rooms:

	Cubic feet of space
Living rooms, one exposure	25 to 30
" " two "	20 " 25
" " three "	15 " 20
Sleeping rooms	25 " 35
Halls and bath rooms	20 " 30
Offices	25 " 35
School rooms	20 " 30
Factories and stores	30 " 50
Assembly halls and churches	40 " 70

Allowance should be made for exposure, construction of building, etc., as in the preceding rule.

Table of Averages

If it is desired to ascertain the approximate size of pipe required without reference to the cooling surfaces, but only taking into consideration the dimensions of the room, the following table may be used.

TABLE 2 (Wm. G. Snow)

Table showing the proper size of furnace pipes to heat rooms of various dimensions, when two sides are exposed. Temperature at Register 140 degrees, Room 70 degrees, Outside zero. Rooms 8 to 17 feet in width assumed to be 9 feet high. Rooms 18 to 20 feet in width assumed to be 10 feet high. For other heights, temperatures or exposures make a suitable allowance. When first-floor pipes are longer than 15 feet, use one size larger than that stated.

Table II. Width of Room

	8	9	10	11	12	13	14	15	16	17	18	19	20
8	8 8												
9	7 8	8 8											
10	8 8	8 8	8 8										
11	8 8	8 8	8 8	8 9									
12	8 8	8 8	8 9	8 9	8 9								
13	8 8	8 9	8 9	8 9	8 9	8 10							
14	8 9	8 9	8 9	8 9	8 10	8 10	8 10						
15	8 9	8 9	8 9	8 10	8 10	8 10	9 10	9 10					
16	8 9	8 9	8 10	8 10	8 10	9 10	9 10	9 11	9 11				
17		8 10	8 10	8 10	9 10	9 10	9 11	9 11	9 11	9 11			
18		8 10	8 10	9 10	9 10	9 11	9 11	9 11	9 11	10 12	10 12		
19			9 10	9 10	9 11	9 11	9 11	9 11	10 12	10 12	10 12	10 12	
20			9 10	9 11	9 11	9 11	9 11	10 12	10 12	10 12	10 12	11 13	11 13
21				9 11	9 11	9 11	10 12	10 12	10 12	10 12	11 13	11 13	11 13
22				9 11	9 11	10 12	10 12	10 12	10 12	10 13	11 13	11 13	11 13
23					10 12	10 12	10 12	10 12	10 13	10 13	11 13	11 13	11 13
24					10 12	10 12	10 12	10 13	10 13	10 13	11 13	11 13	11 13
25						10 12	10 13	10 13	10 13	10 13	11 13	11 13	12 14
26						10 13	10 13	10 13	10 13	11 13	11 13	12 14	12 14
27							10 13	10 13	11 13	11 13	12 14	12 14	12 14
28							10 13	11 13	11 13	11 13	12 14	12 14	12 14
29								11 13	11 13	11 13	12 14	12 14	12 14
30								**11** **13**	**11** **13**	**12** **14**	**12** **14**	**12** **14**	12 14

In the space opposite the numbers indicating the length and width of room, the lower number shows the size pipe for first floor, the upper number the size pipe for second floor. (See Table 2, Page 55.)

For third floor use one size smaller than for second floor. For rooms with three exposures increase pipe given in table in proportion to the exposure. For halls use pipe of ample size to allow for loss of heat to second floor.

One 12″ pipe equals two 9″ pipes.
" 13″ " " " 10″ "
" 14″ " " " 11″ "
" 15″ " " " 12″ "
" 16″ " " " 12″ "
" 17″ " " " 13″ "

Wall Pipe

There are such vast numbers of various styles and sizes of wall pipe and pipe fittings, that we have not space to detail herein, but we will be glad to refer those interested to various manufacturers of such goods.

Manufacturers of Wall Pipe submitted their production to an exhaustive test. We can only place before our readers the results of those tests, which showed as follows:

Single wall asbestos-covered pipe shows little, if any, superiority over single wall pipe, and is said to be inferior to double wall pipe in all particulars. The single wall asbestos-covered pipe is subject to the same structural weaknesses as single wall pipe, and is not as efficient as the double wall pipe.

Double wall pipe is most efficient of the three types, as a means for conveying warm air, and is structurally superior to the other types, and less likely to be imperfectly installed, and is more durable.

The general principles governing design of double wall pipe tend to make the use of this class of pipe far better in every respect than the single wall or single wall asbestos-covered pipe.

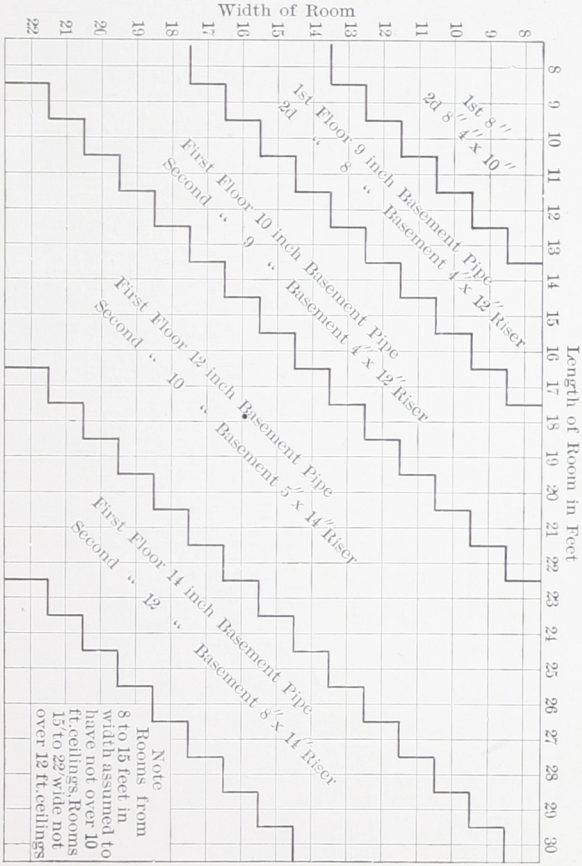
First Floor Pipe and Sizes of Risers

Installers of warm air heaters must lend their aid in persuading architects and builders, as well as

owners to consider carefully the proper size of risers in order that the heating system will not be handicapped by too small an area in those risers.

The chart shown below will also be found valuable in determining sizes of pipes and registers for heating rooms of various sizes.

To use this table, note where the intersection of width and length lines fall, and the sizes of piping required will be found within the enclosed heavy lines.



General Directions and Rules of Piping for the "Richardson" System of Heating and Ventilation

The capacity ratings, piping, ventilating and other tables and directions published in this edition, depend for their validity upon the application of the following rules, which embody sound principles of warm air heater installation:

Each warm air pipe should have an upward pitch from the heater of not less than 1 in. per foot.

The pitch of all warm air pipes should be alike. Equalize by bringing down lower into the cellar the boxes of the shorter warm air pipes.

The table of warm air piping applies where cellar or basement pipes are not over 15 ft. in length. When a warm air pipe in cellar is more than 15 ft. in length, add $\frac{1}{2}$ in. to the diameter of such pipe for each 5 ft. or part thereof, of length in excess of 15 ft., or, when odd $\frac{1}{2}$ in. sizes of pipe are not used, add 1 in. to diameter of pipe for each 10 feet, or part thereof, of length in excess of 15 feet; in such cases, the capacity of the riser must be increased to equal the capacity of the cellar pipe.

An offset in the riser pipe is equivalent to an addition to the length of the cellar pipe, and should be counted in when measuring the total length of the cellar pipe.

All warm air pipes in cellar or basement should be covered with non-conducting pipe covering.

All warm air risers should be carried up in inside partitions, wherever possible, and should be carefully insulated. (In using double wall pipe the capacity should not be reduced.) In cases where it is absolutely necessary to carry up warm air risers in outer walls, such risers should be so thoroughly protected with covering as to be completely insulated.

A separate compartment should be made in the crown or bonnet of the heater for each extra long or winding air pipe, thus insuring a positive supply of warm air to that pipe.

The heater casing should be lined inside with corrugated tin, which is the best means of insulating.

Locate the heater so that the shorter pipes will run to the cold side of the house, West and North, with the longer pipes running South and East.

Never use smaller than eight (8) inch pipe.

When warm air pipes are taken out of the top of the bonnet of the heater, the tops of all the elbows should be on a level, so that an equal current of air can fill all the pipes.

EXAMPLE:

As a 12-inch elbow is so much higher than an 8-inch elbow, in order to have both pipes work properly, the top of the 8-inch elbow should be as high as the top of the 12-inch.

This applies to all pipes taken from the top of the heater.

The same rule applies as nearly as possible where pipes are taken from the side of the bonnet.

Rooms on the North and Northwest sides of the house should always have one size larger pipes and registers than the same sized rooms on the South, Southeast and Southwest sides of the house. Rooms having bay windows and considerable more than the average glass surface on the Northern sides of the house, should have two sizes larger warm air pipes and registers than the same sized rooms without this extra glass surface on the Southern sides.

Where warm air pipes pass through a wall in the cellar, an air space around the pipes should always be left. Never mason a pipe in solid that passes through a wall in the cellar, as the wall chills the pipe and makes that pipe almost worthless.

All pipes should have warm air dampers close to heater, so heating can be regulated.

All rising pipes in partitions or walls to be enlarged or boxed out where cellar pipes enter them. This is necessary to avoid friction and insure rapid flow of air.

Heating two rooms from one pipe on same floor: Always put in division piece, running from top of

register to a point 12 inches below bottom of register. This insures quick flow of warm air to both rooms.

All rising pipes running from second to third floor should always have damper above the register on second floor. Rising pipes should be wrapped with asbestos and studs lined with tin. Use wire or iron lath to plaster on.

Friction: Abrupt bends or acute angles in warm air pipes must be avoided.

Fireplaces in rooms having flues $12 \times 12 = 144$ inches, or $8 \times 12 = 96$ inches or $8 \times 8 = 64$ inches, will in cold or windy weather pull off more air than the warm air pipes can deliver. In such cases, use sheet-iron throat pieces with sliding damper, which makes the ventilation as much or little as desired.

In heating a dining room on the cold side of the house (room having a large amount of glass surface), place one register in the floor as near as possible to the heater. Place a cold air register face in the floor under or near the window, and connect this cold air register by means of a separate duct to the bottom of casing, or into the cold air box. This insures perfect circulation, drawing the cold air out of the room and at the same time drawing the warm air into the room.

The heater should be attached to a chimney flue of correct construction, one that will furnish sufficient draft to insure a good combustion of fuel. (See table of chimney flues, page 77.)

The fresh air supply to the heater must be adequate. (See pages 72 and 73.)

To Builders, Architects and Owners:

It is necessary for our Company to solicit the aid of Builders, Architects and Owners, in providing the proper size risers to the various floors, in order that the number of square inches necessary for the heating requirements of any one room will be found available by the installer of the warm air heater.

If this important matter is taken up when the building is planned, no difficulty will be met. If

however, risers are of a width of more than three times their depth, they will prove a handicap to successful heating.

We feel sure that this is a constructional point which all interested in this method of heating will carefully consider.

Rate of Combustion—Averages

In a compilation of the results of all our tests of Warm Air Heating Apparatus, we have come to the belief that the proper rate of combustion must be based on the square foot of grate and 6 lbs. of coal per hour burned thereon. This rate of combustion is based also on the theory that the heater should deliver enough heat for the requirements of the building at an outside temperature of zero.

In considering this result of our tests, it seems that certain eliminations can take place which materially reduce the total combustion through a given winter season. Insomuch as a 6 lb. rate of combustion is decided upon as being sufficient at zero weather, should the weather average warmer than zero, this rate of combustion will be materially decreased. In figuring average winters, the weather has shown to be considerably above the zero mark.

With the outside temperature at zero, the demands of the system call for a temperature within the building of 70 degrees. At such times of day or night when 70 degrees is not desired, we come again to a point where the rate of combustion can be materially decreased.

In reference to these suggestions, we refer to the result of the 210-day test shown on pages 12 and 14. We claim, without any qualification whatsoever, that to heat an interior to 70 degrees (the thermometer outside being at zero) a 6 lb. rate of combustion can be accepted as a minimum. In heaters having grates larger than 24 ins., a rate of combustion of 7 lbs. of coal per sq. ft. of grate per hour is the maximum. (See various rates of combustion, page 64.)

Goods manufactured along the lines of sensible

construction and benefiting by the proper proportions of surfaces—fire and flue and grate—can be shown to be: first, economical in the consumption of fuel; second, absolutely gas-tight; third, durable to the greatest degree. The idea of price must be considered last of all, if installers and manufacturers wish to satisfy the users of Warm Air Heaters.

Authorities say (Carpenter, Hoffman, International Correspondence Schools) that Warm Air Heaters are not properly constructed unless they bear certain proper ratios of fire surface, flue surface and grate surface. This opinion cannot afford to be laid lightly aside; it is of vital importance to the future of the Warm Air Heating industry.

Capacity Ratings

Depend on Rate of Combustion

In considering the capacity of any Warm Air Heater, attention must be paid primarily to the rate of combustion necessary to supply that rating. This merely means the burning of coal faster or slower, as the case may be. To burn coal at too fast a rate means more frequent feeding of the heater, and an increased cost of fuel for each winter season.

Every **"Richardson"** Heater is sold under a guarantee as to its perfection in manufacture and its ability to carry the ratings shown, provided that a sufficient area of piping is installed for each room of each floor—the piping properly run in accordance with our rulings and suggestions—the heater itself connected to a flue of sufficient size and draft in proportion to the size of the firebox—and a cold air supply of not less than four-fifths of the capacity of the cross-section pipe area taken from the heater, set and installed in accordance with our suggestions and rules.

The following pages are intended only as a comparison of Richardson & Boynton Company's Warm Air Heaters as they are, and at which they would be rated at higher rates of combustion. For full detail measurement, see lists.

Comparing Rated Capacities

In looking over the various ratings or capacities of Warm Air Heaters as are given by some manufacturers, it will be found that they have not, up to the present, been based on any definite rate of combustion.

In many instances, it is found, in order to supply the particular rating of a heater that coal must be burned at a rate of combustion as high as 8 lbs. per square foot of grate per hour.

Some manufacturers will claim that this is the correct amount for large grates, but it is entirely too high for Warm Air Heaters, and it is the intention of this company to submit the tables on the following page in order that the reader may be able to make a comprehensive comparison of the Richardson & Boynton Co.'s Warm Air Heaters to insure himself as to the relative value of the printed ratings and capacities.

It has always been our intention to rate our heaters on such a basis that we can safely guarantee results under normal conditions.

In order to get the full efficiency from any heater, it must be so constructed that it benefits by the proper proportions of various surfaces within the heater.

We have established for our goods a rate of combustion of 6 lbs. of coal per square foot of grate per hour. This rate of combustion for residence heating does not require attention more than once in eight hours. In increasing the capacity of this heater, it would be necessary to feed at more frequent intervals, and use up the coal much faster.

We print on Page 61 certain suggestions as to average rates of combustion through winter seasons, and that information, used in conjunction with the following table, will prove comprehensive to any installer or user of our goods.

We have proved it to be impossible to obtain, at a fixed rate of combustion, the same efficiency from a heater of inadequate construction and small amount of heating surface, as can be obtained from modern goods benefiting by the correct proportion of various surfaces.

What Ratings Mean to the Owner

The following table shows, in columns 5, 6, 7, 8 and 9, the number of square inches cross-section heat pipe capacity at the various rates of combustion.

Column 4 represents the rated capacity in Richardson Heat Units per heater.

IMPORTANT

Showing ratings of our Warm Air Heaters, as they are and as they would be, burning coal at 6, 6½, 7, 7½ and 8 lbs. per square foot of grate per hour.

	1	2	3	4	5	6	7	8	9
	No. of Heater	Diameter of Grate, Inches	Diameter of Pot, Inches	Our Rating Richardson Heat Units	Burning 6 Lbs. of Coal per Sq. Ft. of Grate per Hour	Burning 6½ Lbs. of Coal per Sq. Ft. of Grate per Hour	Burning 7 Lbs. of Coal per Sq. Ft. of Grate per Hour	Burning 7½ Lbs. of Coal per Sq. Ft. of Grate per Hour	Burning 8 Lbs. of Coal per Sq. Ft. of Grate per Hour
	900	16	18	**312**	311	328	353	379	403
"Perfect"	**901**	19	21	**418**	418	437	470	504	538
Positive	**902**	22	24	**560**	507	532	573	614	655
Series	**904**	24	26	**665**	644	673	726	778	829
	906	27	29	**835**	814	856	922	988	1054
	908	31	33	**1150**	1150	1209	1302	1395	1488
	131	14	16	..	..	..	..	..	..
	135	16½	18½	**274**	274	289	311	333	355
New	**141**	19	21	**368**	368	384	413	443	473
"Perfect"	**144**	22	24	**446**	446	468	503	540	576
Series	**148**	24	26	**566**	566	593	638	684	730
	157	27	29	**716**	716	753	811	868	927
	163	31	33	**1013**	1013	1063	1145	1226	1308
	171	38	40	**1459**	1459	1533	1651	1768	1886

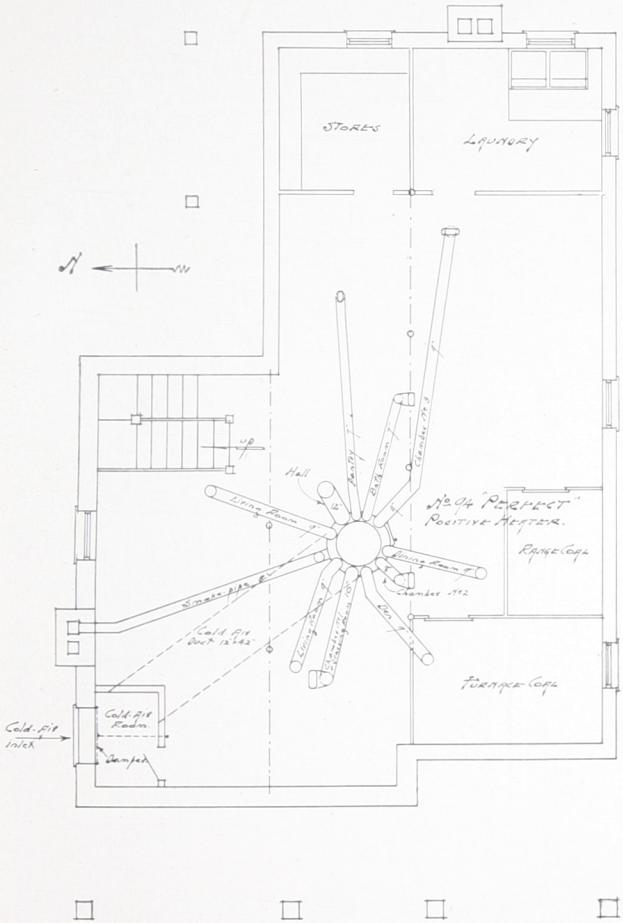
(See Page 9. Comparative Test.)

Speculative		..	21	**273**	..	..	..	300	320
Heaters		..	24	**401**	..	..	..	405	432
Average Sizes		..	26	**508**	..	..	..	510	543
		..	29	**576**	..	..	..	582	620

A "Richardson" Heat Unit (see definition, Pages 5 and 7) is a definite measure of heat, and is a more logical basis for rating heaters than any heretofore used.

Richardson & Boynton Co.

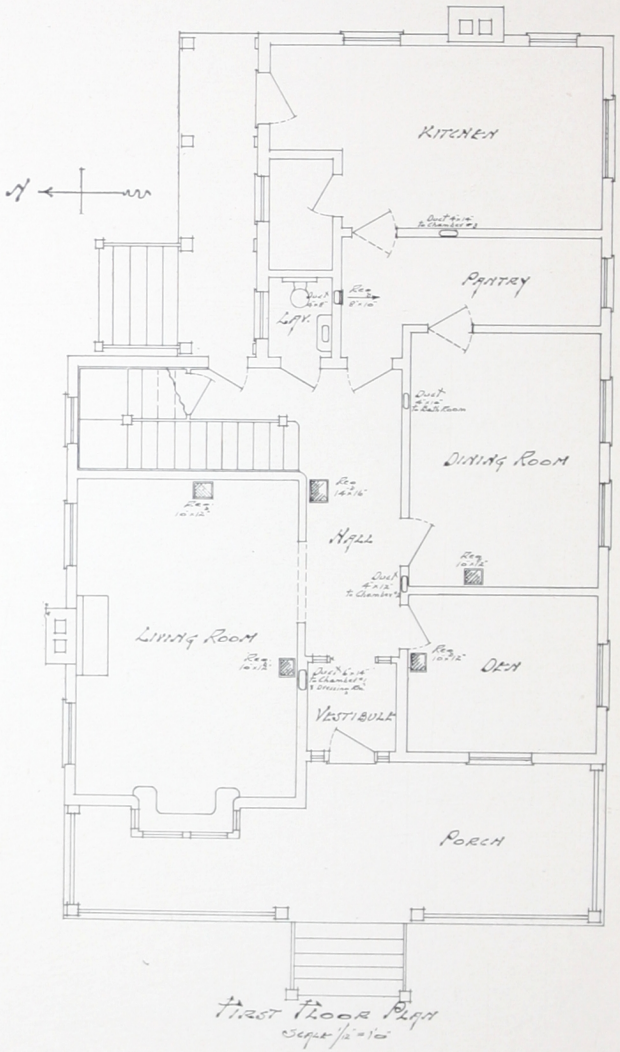
House Plan 1



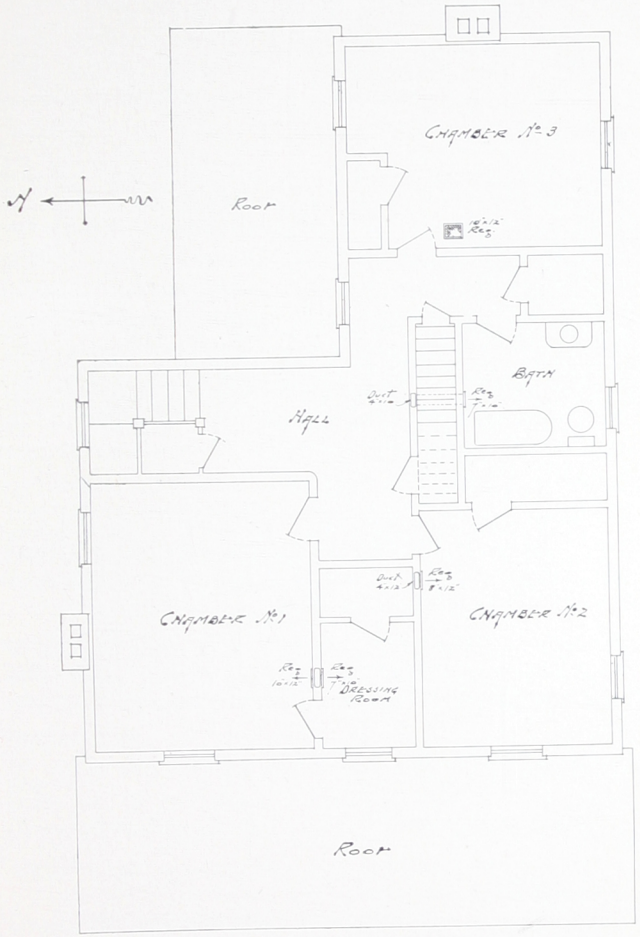
CELLAR PLAN
Scale 1/2 in.

Richardson & Boynton Co.

House Plan 2



House Plan 3



SECOND FLOOR PLAN
SCALE 1/2"=1'0"

SCHEDULE

Rooms	Wide	Long	High	Cubic Feet	Glass Surface Sq. Ft.	Wall Surface Sq. Ft.	Glass & Equivalent Sq. Ft.	Total Cu. Ft. Air to be Heated	Area Warm Air Duct R. H. U.	*Corrected Area R. H. U.	Cellar Pipes Inches	Partition Pipes Inches	Registers Inches
First Floor													
Living room	14	21	9	2646	94	302	124	11946	110	121	2–9	..	2–10x12
Den	10	12	..	1080	44	172	61	5655	52	57	9	..	10x12
Dining room	12	16	..	1728	44	100	54	5778	53	53	9	..	10x12
Pantry	6	17	..	918	15	57	21	2493	23	23	7	4x 8	8x10
Hall (front)	6	18											
" (rear)	6^6	14^6		3699	68	322	100	11199	103	113	12	..	14x16
" (sec. fl.)	6^6	34	8^6										
Second Floor													
Cham. No. 1	14	17	8^6	2023	33	231	56	6223	57	57	10	6x14	10x12
Dressing room	6	8	..	408	15	36	19	1833	17	17	...	..	7x10
Cham. No. 2	12	15	..	1530	30	200	50	5280	49	49	8	4x12	8x12
Cham. No. 3	12^6	16	..	1700	30	327	63	6425	59	59	9	4x14	10x12
Bath room	8	9	..	612	12	56	18	1962	18	18	7	4x10	7x10

No. 94 **"Perfect"** Positive Heater.
Smoke flue not less than 8 ins. or equal.

T't'l 567 Richardson Heat Units.

Remarks

* Corrections for Exposure: First Floor, south rooms, .0092; north or west rooms and halls, .0092 and add 10 per cent. Second Floor, south rooms, .0092 and deduct 10 per cent.; north or west rooms and bath rooms, .0092.

Example.—What area of warm air duct will be required to warm living room shown on plans, the outdoor temperature being zero and room temperature to be 70 degrees?

Cubic contents of room.....$14' \times 21' \times 9' = 2646$
Sq. ft. of glass surface..... 94
" exposed wall surface..... 302

Equivalent glass surface in wall exposure, $302 \div 10 = 30$ sq. ft.

Amount of air cooled by glass and equivalent, $94 + 30 \times 75 = 9300$ cu. ft.

Total cu. ft. of air to be heated, $2646 + 9300 = 11946$.

Area of warm air duct required $11946 \times .0092 = 110$ Richardson Heat Units.

Correction for north and west exposure, $110 + 10$ per cent. $= 121$ Richardson Heat Units, the area required.

Explanatory Notes of House Plan

It will be noted that the pantry cellar pipe, and bath room cellar pipe, show 7 in. We make a strong plea that nothing less than 8 in. be used. But we show a plan which has been installed, and most satisfactorily; but where these two 7 in. pipes were used, we advise 8 inch.

This particular installation was laid out in accordance with requirements for stock size of registers. Certain variation in the size of registers may be allowed, but installers generally find it more convenient to purchase stock sizes. This example will show that in most instances they are satisfactory.

Note, on the First Floor plan, full furred out size of the vestibule partitions, which allows for a riser to the Second Floor 6×14 in. Partitions amply large for proper sizes of riser pipe are easily obtained through permission of architects, if the installers make their plea early enough and while the plans are being considered.

It is well to note, in measuring two rooms of practically the same heating requirements, that the differences in the size of the pipe area must be accounted for by reason of the exposure of one particular room.

You will note by our Rule 1, additions and deductions of 10 per cent., depending upon the figured exposures of rooms located to the North and Northwest.

In the West and Northwestern sections of the country 10 per cent. is added to North and Northwest exposures—but no deductions for South and East.

See page 49 (Western practice).

Richardson System of Combination Warm Air and Hot Water Heating with Outdoor Fresh Air Supply for Warm Air Section

In a house heated with warm air some of the rooms may be more conveniently heated by direct hot-water radiation. This is especially true of low, rambling structures with many rooms on one floor. The rooms which are more frequently occupied, or in which the largest number of people congregate, such as living room, etc., should be supplied with plenty of fresh air for heating and ventilating purposes. The other rooms may be heated by hot water combination.

The principal difficulty experienced in combination systems is in maintaining a proper balance between the warm air and hot water parts of the system, so that one will not heat at the expense of the other. It is advisable to place both a register and a radiator in the hall, either of which should be of ample size to heat the hall alone, so that by using one or the other a proper balance between the different parts of the system may be maintained.

Figure by Richardson Rules the heating requirements of the room which is to be heated by means of hot water. (See pages 44-48.)

Use 1 sq. ft. of hot water direct radiation for each Richardson Heat Unit required.

The following table gives average ratings in square feet of direct hot water radiation, which may be kept at a temperature of 160 degrees, in the forms of water heating devices usually employed in combination warm air and hot water systems:

	Square ft. direct hot water radiation per sq. ft. of heating surface in water heater.
Cast-iron sections entirely above fire	15 to 20
Cast-iron sections in contact with fire	40 to 60
Cast-iron sections partly above and partly in contact with fire	25 to 35
Pipe coil entirely above fire	20 to 25
Pipe coil buried in fire	50 to 60
Pipe coil partly above and partly buried in fire	30 to 40

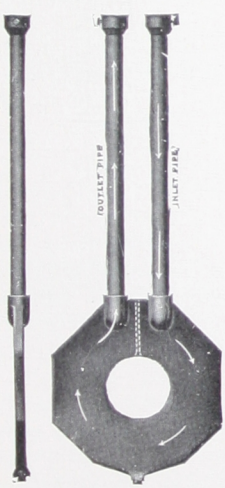
Water Heating Disks

For Hot Water Heating in Combination with Warm-Air Heating

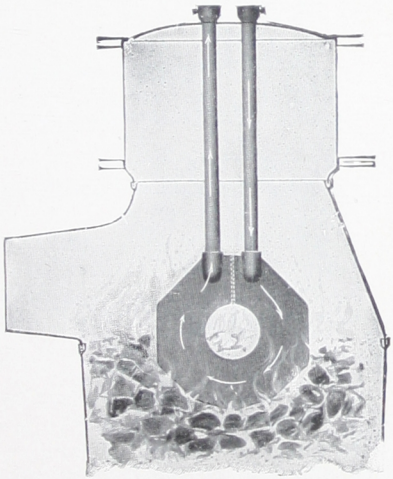
SIZES Inches	Radiation Rating Square Feet	Should be placed in Pots of Inches Diameter	Price
12	150	24	**$17.50**
14	200	26	**22.00**
16	275	29	**26.50**
18	350	33	**30.50**

These are powerful hot water heating attachments for heating radiation in combination with warm air heating. Are placed inside the pots with pipes up through the center of radiator, thus hanging in position, and being placed inside the hottest part of the fire will do the work easily and effectively, and circulate water even with a low fire.

The heating power is largely dependent upon whether disks are placed in a smaller or larger fire-pot; the same disk inside a larger body of coal will heat more than if put in a smaller body of coal. Disk should be hung in center of pot, about seven inches above the grate, with the edge of disk toward the feed door.



End View Side View



Side View as placed inside Furnace

General Directions and Rules Governing Cold Air Supply

For the "Richardson" System of Warm-Air Heating and Ventilating

Always bring the cold air box from the coldest side of the house—West, Northwest, or North.

Cold air boxes when taken from the outside should be equal to four-fifths ($\frac{4}{5}$) of the total warm air pipe capacity. When air is taken from inside of the house, the cold air opening into the heater should be of equal capacity to all of the warm air pipes

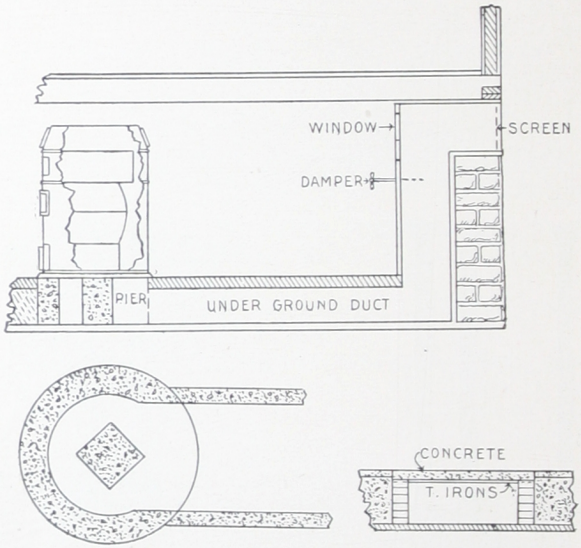


FIG. 1.

Do not take cold air box direct to the heater from East or South. When this is done, it will be noted that hot air frequently comes out of the cold air box or the heater seems to be breathing. A current of warm air will pass up through the pipes and then

suddenly stop, and the air will suck down the register. This condition can be easily overcome by the use of what is called—a cold air room, or air supply chamber. (See page 75.) The best results are always obtained by taking the air from the cold and windy side of the house.

Cold air pit under the heater should never be more than 14 inches deep. (Fig. 1.)

Cold air box opening into casings of heater should never be higher than the total height of ash pit and should enter the heater from the rear to obtain the best results. (Fig. 2.)

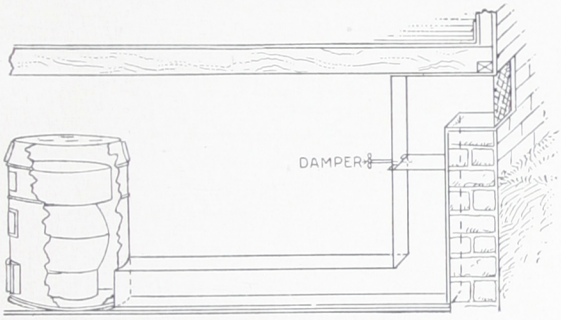


Fig. 2.

Cold air box should have closing damper near the entrance to the house, and also a connecting cold air pipe from the main hall, the full width of the box, and connected near the heater. This is suggested in order to admit air from the main hall during the night or during extreme weather.

The top of all cold air openings should never be above the level of the grate.

Symptoms of Lack of Cold Air Supply

It is absolutely impossible for a heater to supply warm air and cold air at the same time. When such seems to be the case, you will always find that the register through which cold air seems to be coming up from the heater is actually going down to the top of the heater, and then going into the pipes supplying the warm air. In all such cases, the cellar is hot, which shows imperfect circulation. When enough air is not supplied to the heater, it always draws air from the cold side of the house, and it goes down those registers. To prove it, put your handkerchief over the register and you will find it will flatten out, or if you light a match it will draw it down, or smoke a cigar and the smoke will go down the register, as you can see. This shows absolutely that not enough air is supplied to the heater. Take, for example, a heater having only two pipes, one going to the cold side of the house, and the other going to the warmer side. Unless sufficient air is supplied at the bottom of the heater to fill both of those pipes, the cold air will go down the register from the cold side of the house, just strike the top of the radiator, and go up the pipe leading to the warm side. In such cases, one gets practically no benefit of the heat from the firepot and the body and sides of the radiator, only from the top. The result is that the cellar gets very hot and is the warmest room in the house.

The matter of the proper supply of fresh air to the heater is most important, as a satisfactory warm air heating system is dependent, first of all, upon a sufficient volume of air to properly fill the pipes and supply all rooms to be heated with fresh air at a temperature not too high and in sufficient volume to offset the heat losses in the room. The proper size cold air box can readily be determined by reference to rules given in this Manual.

Fresh Air Room

Wherever possible, the construction of a Fresh Air Room is most desirable. The additional cost is small, and it provides for a far better control of wind currents, since, if there is a strong wind blowing directly into the inlet, it is diffused and broken before entering the air duct.

When such an Air Room can be provided, it should be tightly sealed with insulation and sheathing to prevent cooling the floors above.

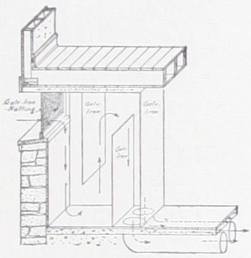


Fig. 3
Fresh Air Room with Dust Collector

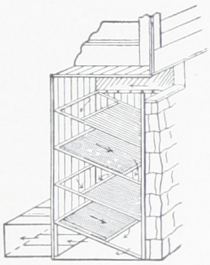


Fig. 4
Fresh Air Room with Filter Screens

If, for cost considerations or other reasons, a Fresh Air Room cannot be provided, that part of the Fresh Air Duct which may descend to the floor of the cellar should be enlarged to not less than double the required capacity, thereby providing a reservoir for fresh air which steadies the supply and prevents high and variable winds from interfering with the regularity of the inflow. Further than that, if a clean-out door be placed in this enlargement, it can easily be kept clean. From the cellar floor to the heater, the fresh air duct should be reduced to the required capacity.

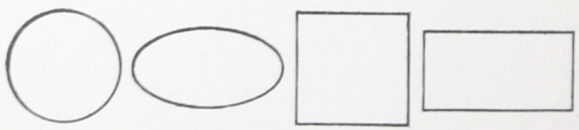
Chimney Flues

There is no other single source which is responsible for so many failures in heating as that of defective chimneys.

It must be impressed upon the prospective user that the heater has no draft; it depends entirely on the chimney flue. The better the chimney flue, the more successful the working of the entire apparatus will be.

1. The heater chimney flue should extend from a point near the cellar floor to a point at least 2 ft. above the highest projection of the roof.
2. The heater chimney flue should have no other opening or connection into it. No range, stove, fireplace or ventilating register should open into it, or be connected with it.
3. The flue should be closed tightly about a foot below where the smoke pipe enters. Tightly fitting clean-out doors should be put in the flue below the smoke pipe opening.
4. There should be no offsets or bends used to reduce in any way the area of the flue, and the inside should be smooth and clean. Projecting mortar holds rubbish accumulations which hamper the draft.
5. An outside flue should have at least two courses of brick on the exposed side.
6. The heater should be connected to the chimney with smoke pipe of the full size of the smoke collar specified in the catalog. This is important.

The best internal shape for a chimney flue, to overcome friction, is round.



First, round; next, elliptical; next, square rectangular

The rectangular chimney flue, which is the form most frequently used, is the least effective.

A rectangular chimney flue should never be less than half as wide as it is long; and the nearer it approaches the square form, the better.

That is, a chimney flue 8×12 is better than one 6×16, though each has the same area.

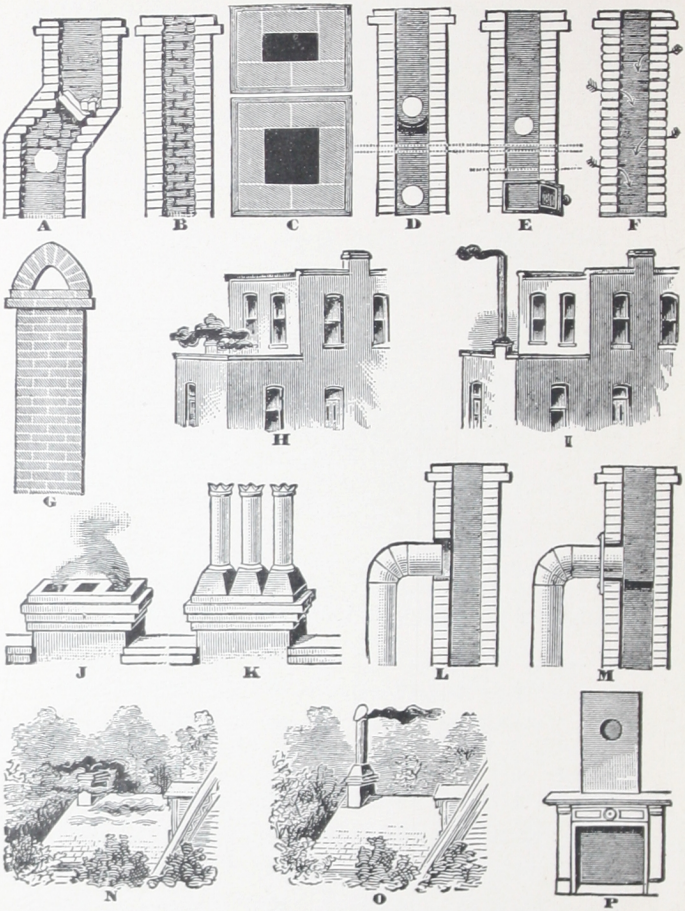
Chimney Flue

After the proper size warm air heater has been determined, the proper size of chimney flue may be determined by referring to Table 3.

TABLE 3

Diameter Round Chimney Flue	Size Square Chimney Flue	Size Rectangular Chimney Flue	Height Chimney Flue Above Grate	Capacity in Richardson Heat Units Anthracite Coal	Capacity in Richardson Heat Units Bituminous Coal
Inches	Inches	Inches	Feet		
8	7½× 7½	6×10	30	205	
9	8½× 8½	8×10	32	340	195
10	9½× 9½	8×12	34	525	325
11	10½×10½	10×12	36	765	500
12	11½×11½	10×14	38	1050	715
13	12½×12½	12×14	40	1290	935
14	13½×13½	12×16	40	1640	1180
15	14½×14½	14×16	40	2000	1460
16	15½×15½	14×18	40	2360	1780
17	16½×16½	14×20	40	2765	2100
18	17½×17½	16×20	40	3225	2460
19	18½×18½	16×22	40	3705	2870
20	19½×19½	18×22	40		3295

Chimneys



Poor Draft to Chimney

Good Draft to Chimney

Poor Connection and No Draft

Proper Smokepipe Connection

Chimneys

Note illustrations on preceding page, showing defects in chimney flues quite frequently found in unsatisfactory heating plants. Care should be taken by installers of warm air heating systems to avoid these common causes of trouble.

Filled with brick and mortar (A); they should be clean.

Rough inside (B); should be smooth.

4 x 8 inside (C); should be 9 x 9 or 9 x 13.

Several stoves connected (D); should be but one.

Openings in the basement (E); should be closed so no air can get in.

Cracked outside (F); cracks should be filled.

Arches (G); should have stack, I or K.

Lower (H); should be higher than any part of the house (I).

Flat on top (J); should have finish (K).

Pipe cut off at brick line with hole open around it (L); should extend one inch inside of opening, and made air-tight (M).

High trees surrounding (N); remedy, high revolving hood (O).

Open fireplace with range connected (P); close fireplace air-tight.

Constructing a chimney by extending the flue downward to the floor, and in many cases into the cellar, creates a place for the accumulation of soot, ashes, etc., so as to save the expense of cleaning the flue, then the cold air below the pipe-hole *chills the entire column of air in the chimney;* it is therefore heavy, and impedes the ascent of the smoke. The remedy is to either fill the flue with cement to within six inches below the pipe hole, or cut off the flue with a sheet-iron plate, the plate to be covered with several inches of cement, so as to make it air-tight. The result will be to apply the heat at the base of the flue, and a good draught obtained.

Ventilation

The question of ventilation in conjunction with heating is one to which the great public is giving closer and closer attention. This is proven by the fact that the New York *Times* of October 26, 1913, printed a very exhaustive article bearing on the efforts of a certain Commission which had been formed and financed from a bequest of the late Mrs. Elizabeth Milbank Anderson, to give four years to experimentation and search into this most important of all questions.

The head of the Commission is Prof. Winslow, who has written extensively on this subject. He is aided by: Mr. Edward Lee Thorndike, in charge of the experiments which the commission will undertake; Mr. D. D. Kimball, Civil Engineer and Expert on Ventilating and Heating: Dr. James Alexander Miller, Professor of Clinical Medicine and an authority on tuberculosis; Dr. Frederick S. Lee, Professor of Physiology at Columbia University; and Mr. Earl B. Phelps, Chief Chemist in the Hygiene Bureau at Washington.

This commission has in mind improvement in the conditions surrounding heating and ventilating in churches, schools and factories, and will even go farther, insomuch as they will be ready to advise as to the proper ventilating of homes. They hope, during their four years of experimentation, to be able to give definite suggestions as to the value of a ventilating system within our homes, and, at the same time, advise the public as to the proper degrees of temperature, cubical quantities of air, and proper proportions of relative humidity.

There have been so many varying opinions that the results of this commission's work will be looked forward to with great interest. In the meantime, the fact that this commission is going on with the big work, cannot help but impress us as to the necessity of all house owners considering ventilation in conjunction with their heating system.

Richardson System of Ventilation

Ventilation is the process of renewing or changing the air in a building so that it may be kept in a sufficiently pure state to be healthful for breathing, notwithstanding the continual tendency to vitiation from the breath of occupants, the burning of illuminants, etc.

Adequate and proper ventilation is an inseparable and essential part of our problem.

Ventilation, in fact, is even more important to health than heating. It is possible we could exist, even in rather cold climates, without artificial heat; but, whether our houses were heated or not, if our rooms were shut up tight, allowing no ventilation, we would suffocate.

While it is one of the merits of the **Richardson System** that it is impossible to heat a building, with our system, without at the same time changing the air,—yet the heating is more successfully accomplished, and the ventilation is more certain and sanitary, where a system of ventilation is installed as a part of the heating plant.

Although we have an unlimited amount of fresh air, many of us do not endeavor to bring it into our homes, but breathe an impure atmosphere indoors during the winter season.

The open fireplace or grate cannot be depended upon for ventilation, except for the room in which it is placed, and even in that room it is a poor method of ventilation.

For instance, there is not likely to be any ventilation unless there is a fire in the fireplace or grate, and even with a fire, the volume of air removed from the room is very seldom properly proportioned to the size of the room. If an excessive amount of air be removed, the additional air supply to replace the outgoing air will be forced in through crevices or openings, thus making more difficult the process of heating, as well as causing drafts and currents of cold air. We advise that a ventilating register be installed in a room containing an open fireplace or grate; and this ventilating register may be closed when there is a fire in the open fireplace or grate.

Construction of Ventilating System

It is advisable that a large stack or shaft should be provided for instead of an ordinary chimney flue, and a pipe of metal, or tightly joined terra-cotta, run up through this shaft for the draft or heater flue. Cast-iron pipe or cast sewer pipe is admirably adapted for this purpose. The space left within the shaft, outside of the pipe, will form the main channel of ventilation. Connect a duct or flue from the ventilating register in each room to be ventilated, to the main ventilating shaft. Ventilating registers to be located in inside partitions (at the floor line) or in the floors, and not in the outer walls. When the warm air register is located near the floor, the ventilating register should be placed at least 4 ft. from the warm air register. When joists and girders are so laid out that they will not permit the ventilating duct to be connected to the shaft, the ventilating duct from the individual room should be carried up to the top floor,—or, if the room to be ventilated is a first-floor room, the duct should be carried down to the cellar through some partition, and connected in the cellar to the main shaft.

The smoke pipe within the main ventilating shaft being considerably higher in temperature than the shaft, an upward current of considerable strength will be caused, and this tends to draw in the air through every ventilating register which is connected to the main ventilating shaft. In many instances, a double flue is built, providing both a ventilating shaft and a smoke exit, the larger part being used for ventilating. The partition between these two flues should be absolutely tight. Unless a ventilating shaft is warmed, an upward current of air will not prevail to any marked degree, and unless the ventilating shaft is warmed, no satisfactory results can be obtained.

When the system is operated under pressure, either Exhaust or Fan, the heating of the main shaft is not so essential.

It is much more difficult to properly heat an unventilated room than one in which ventilation is provided.

Ventilating Ducts and Registers and Main Ventilating Shaft

Where special ventilation is to be effected by means of ventilating ducts and registers, and a main ventilating shaft, proper sizes of these may be determined after the heat requirements of the room in **Richardson Heat Units** have been calculated, by referring to Tables 4 and 5, which follow.

TABLE 4

Sizes, Capacities, etc., of Ventilating Ducts and Registers

Diameter of Round Ventilating Duct in Inches	Area of Round Ventilating Duct in Sq. Inches	Size Flat Ventilating Duct in Inches	Corresponding Size of Register in Inches	Capacity in Richardson Heat Units Any Floor
5	20	3 × 6½	6 × 8	36
6	28	3 × 9½	8 × 8	52
7	38	3½ × 11	8 × 10	71
8	50	3½ × 14	8 × 12	93
9	64	4 × 16	10 × 12	117
10	78	4 × 20	12 × 12	145
11	95	6 × 16	12 × 15	176
12	113	6 × 19	14 × 15	210
13	132	6 × 22	14 × 18	245
14	154	8 × 19	16 × 18	287
15	176	8 × 22	16 × 20	328
16	201	8 × 25	18 × 20	374
17	227	10 × 22½	18 × 24	423
18	254	10 × 25½	20 × 24	472

TABLE 5

Sizes, Capacities, etc., of Main Ventilating Shaft

Dimensions of Main Ventilating Shaft with Chimney Flue in the Center Inches	Dimensions of Main Ventilating Shaft with Chimney Flue Adjoining Inches	Capacity in Richardson Heat Units	Dimensions of Main Ventilating Shaft with Chimney Flue in the Center Inches	Dimensions of Main Ventilating Shaft with Chimney Flue Adjoining Inches	Capacity in Richardson Heat Units
14 × 14	8 × 10	160	18 × 29	12 × 28	710
14 × 17	10 × 10	200	20 × 30	14 × 26	775
16 × 16	10 × 12	245	20 × 31	14 × 28	840
16 × 17	10 × 14	285	20 × 33	14 × 30	905
16 × 19	10 × 16	325	22 × 32	14 × 32	970
18 × 20	10 × 18	370	22 × 34	16 × 30	1045
18 × 21	10 × 20	410	22 × 35	16 × 32	1120
18 × 22	10 × 22	450	24 × 36	16 × 34	1200
18 × 23	12 × 20	500	24 × 37	16 × 36	1275
18 × 26	12 × 22	550	24 × 38	18 × 34	1360
18 × 27	12 × 24	605	24 × 40	18 × 36	1450
18 × 28	12 × 26	655			

Volume of Air Necessary for Standard of Purity

Cu. Ft. of Space in Room per Individual	Proportion of Carbonic Acid in 10,000 Parts of the Air not to be exceeded at end of hour						
	6	7	8	9	10	15	20
	Cubic Feet of Air, of Composition Four Parts of Carbonic Acid in 10,000, to be supplied the first hour						
100	2900	1900	1400	1100	900	445	275
200	2800	1800	1300	1000	800	345	175
300	2700	1700	1200	900	700	245	75
400	2600	1600	1100	800	600	145	None
500	2500	1500	1000	700	500	45	...
600	2400	1400	900	600	400	None	...
700	2300	1300	800	500	300	...	...
800	2200	1200	700	400	200	...	...
900	2100	1100	600	300	100	...	...
1000	2000	1000	500	200	None	...	...
1500	1500	500	None	None	...	...	...
2000	1000	None			...	...	...
2500	500				...	...	...

Note—Above information is quoted from standard authorities. Not guaranteed.

Testing Installations

Completed installations may be tested at any time of year by means of the following table of outside and inside temperatures (Carpenter).

To Equal a Temperature of 70 Degrees Fahrenheit in Zero Weather

If outside temperature is	It is necessary to maintain an inside temperature of
10 below zero, Fahrenheit	64 above zero, Fahrenheit
zero, "	70 " " "
10 above " "	75 " " "
20 " " "	81 " " "
30 " " "	85 " " "
40 " " "	90 " " "
50 " " "	98 " " "
60 " " "	104 " " "
70 " " "	110 " " "
80 " " "	117 " " "
90 " " "	123 " " "

The Richardson System of Mechanical Warm Air Heating and Ventilation

All systems of heating and ventilation which do not involve the mechanical movement of air in definite quantities have their advantages and disadvantages, but they lack what is getting to be considered as important as heating, namely, positive ventilation. The nearest approach to positive ventilation without the employment of mechanical means for moving the air is found in the gravity warm air heating system such as we advocate for ordinary work with warm air heaters of our manufacture. It frequently happens, however, as in the case of schools and other public buildings, that it is desirable or even compulsory to introduce into the building to be heated, more air than would be necessary to act as a heat carrier. This excess air could not be introduced into the building by the gravity system without at the same time introducing an excessive amount of heat. In such cases as this, the heat requirements and the ventilation requirements can both be satisfactorily fulfilled by the employment of mechanical means for moving the air over the heating surfaces of the warm air heater and into the space to be heated and ventilated.

The mechanical agent usually employed for moving air under these conditions is a fan such as is manufactured by a number of reliable concerns in that line of business. The fan is used in either one of two ways. First, by placing it between the cold air inlet and the warm air heater, in order to draw air from the outside atmosphere and force it over the heating surfaces of the heater and thence into the rooms to be heated and ventilated, which arrangement is known as the **plenum system**; second, by connecting it with the vent flues from the various rooms, in order to draw the vitiated air from the rooms, thereby reducing the atmospheric pressure in those rooms to such an extent that more air is drawn from outside through the heater and into the rooms. This latter arrangement is known as the **exhaust system.**

The plenum system is more generally employed than the exhaust system for many reasons, although, in cases where the expense can be justified, combined plenum and exhaust systems may be employed. The plenum system lends itself more readily to the solution of problems involving the washing and humidifying of air, whereas the exhaust system is more adaptable where the rapid removal of malodors is desirable.

The plenum system is preferable to the exhaust system, where the source of heat is a warm air heater, and frequently, even where special ventilation is not required, a fan may profitably be used in connection with a warm air heater, as for instance in the case of the low, rambling type of house which is so popular now.

Proper Size of Warm Air Heater to be Selected for Use with Mechanical Warm Air Heating and Ventilating Systems

It is not our purpose to go into a detailed description of the various modifications of plenum and exhaust systems in general use, but only to give a practical rule for determining the proper size warm air heater to select for use with a mechanical heating and ventilating system.

Having determined the heat requirements of a room in "Richardson" Heat Units by Rules 1 or 2, pages 44 to 48, the number of cubic feet of air per minute necessary as a heat carrier, reduced to the standard temperature of 70 degrees, if the air entered the room at 140 degrees, may be ascertained by the following formula:

$$Q = 1.5\ H$$

in which Q = number of cubic feet of air per minute required as a heat carrier, reduced to 70 degrees.

H = heat loss from the room per hour in "Richardson" Heat Units.

The number of cubic feet of air per minute necessary for ventilation is found by the following formula:

$$Q_v = 30\ N$$

in which Q_v = number of cubic feet of air per minute required for ventilation at 70 degrees.

N = the number of occupants.

If the amount of air required for ventilation exceeds the amount of air required as a heat carrier, the air must be brought into the room at a temperature lower than 140 degrees, and mechanical means are usually provided for moving the air. The temperature t_f, at which the air must be brought into the room to maintain a room temperature of tr, and provide Q_v cubic feet of air per minute for ventilation, or ventilation for N persons, is found by the following formulae:

$$t_f = \frac{101\ H}{Q_v} + t_r$$

or

$$t_f = \frac{3.36\ H}{N} + t_r$$

in which H = heat loss from the room per hour in "Richardson" Heat Units.

Knowing the temperature, t_f, at which the air must be brought into the room to maintain a room temperature of t_r, the number of Richardson Heat Units of heater capacity, which must be allowed for the room, exclusive of piping, etc., may be determined by the following formula:

$$H_h = \frac{t_f - t_o}{2\,(t_f - t_r)}\ H$$

in which H_h = heater capacity in Richardson Heat Units.

t_f = Temperature at which air is brought into room.

t_r = Room temperature.

t_o = Outside temperature.

H = Calculated heat losses in Richardson Heat Units.

To determine the warm air heater capacity for the building, add together the capacity necessary for all the rooms. The result will be the proper size warm air heater to select for the heating and ventilation of the building.

The proper size fan to be used to move the quantity of air required according to the above formula may be selected by referring to the catalogs of reputable manufacturers making that class of goods, care being taken to allow sufficient static resistance for the system so that the fan may be amply large.

The areas of registers, ducts, etc., for use with the "Richardson" system of mechanical warm air heating and ventilation may be determined, after the required quantities of air have been computed, by allowing velocities in feet per minute in accordance with the following table:

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Average Velocities in Feet per Minute for

	Fresh Air Intake	Main Duct Near Fan	Smaller Branch Ducts	Stacks	Register or Other Openings
School, Offices, etc..	850	1500	900	600	300
Churches, Auditoriums, etc.....	850	1800	1200	700	400
Factories and Shops.	850	2000	1500	800	500

In applying the above table it must be borne in mind that the quantity of air as computed from the formulae given is at a temperature of 70 degrees. The actual quantity leaving the register would be

$$Q_f = \frac{T_f}{530} Q_v$$

in which Q_f = quantity of warm air leaving register per minute.

Q_v = quantity of air per minute at 70 degrees as computed from the formulae.

T_f = absolute temperature of air leaving register.

Velocity: "Rule for Determining Area, Velocity, and Volume of Ducts."

Cubic feet of air per minute through duct equals area in square feet times velocity of air in feet per minute.

Velocity of air in feet per minute through duct equals cubic feet per minute divided by area of duct in square feet.

Area in square feet of duct equals cubic feet of air per minute divided by velocity in feet per minute.

Humidity

The term *humidity*, as applied to the air we breathe, refers to the amount of moisture present in the air in the form of water vapor. It may be indicated in either of two ways,—as *absolute humidity*, by which term we mean the actual amount of moisture present in a cubic foot of air at a given temperature and percentage of saturation, and which is usually expressed as grains per cubic foot; or as *relative humidity*, by which term we mean the ratio of the weight of water vapor in a given space as compared with the weight which the same space is capable of containing when fully saturated at the same temperature. Or, to express the same idea in different words, the relative humidity of air at any temperature and percentage of saturation is the ratio of the absolute humidity for the given condition to the absolute humidity at saturation.

If air at any temperature and percentage of saturation is cooled without any moisture being added to or taken from the air, the temperature at which saturation is obtained, or the point where any further reduction in temperature would cause condensation of some of the water vapor, is called the *dew point.*

It must be borne in mind that the weight of water vapor a given space will hold is dependent entirely on its temperature. The amount of vapor in any given space is independent of the presence of air, the only effect the air has being due to its temperature. The converse is not true, however, as the presence of water vapor in any space makes it impossible for as much air to be present as though the air were perfectly dry.

The most reliable and most generally used instruments for measuring the humidity in the air have as their basic features a dry bulb and a wet bulb thermometer. The dry bulb thermometer indicates the temperature of the air and vapor, and the difference between the dry and wet bulb thermometers indicates the degree of humidity. If any body moistened with water be placed in a current of air, some of its moisture will be evaporated, depending on the humidity of the air passing over it. This evaporation will extract heat from the moist body and cool it, when, it being cooler than the air current, this air will give up some heat to it. This operation will be continued until the moist body reaches a temperature at which the amount of heat it loses as a result of evaporation is equal to the amount of heat which the air gives up to the moist body. Its temperature will then remain constant, and this temperature is the *wet bulb temperature.*

This is the precise manner in which the air acts upon the human body, and it can be readily seen that the temperature felt by the body, or the sensible temperature, as it is called, corresponds to the temperature of the wet bulb thermometer; hence the drier the air, the greater the difference between the

actual and sensible temperatures. Dry air heated considerably above the normal will still be chilly, slight drafts are very noticeable and colds are easily contracted.

We give below tables showing the relative humidity for different dry bulb temperatures and different wet bulb depressions, and also the various properties of dry air and mixtures of air and vapor.

Air Temperature	Relative Humidities Difference in Degrees Between Dry and Wet Bulb Thermometers																		
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
30	100	78	57	36	17														
35	100	82	65	45	28	12													
40	100	84	68	53	38	22	8												
45	100	85	71	58	44	32	19	7											
50	100	87	74	61	50	38	27	16	6										
55	100	88	76	65	54	43	34	24	16	6									
60	100	89	78	68	58	48	39	30	22	14	6								
65	100	90	80	70	61	52	44	35	28	20	13	6							
70	100	90	81	72	64	55	48	40	33	26	19	13	7	1					
75	100	91	82	74	66	58	51	44	37	31	24	19	13	7	2				
80	100	92	83	75	68	61	54	47	41	35	29	23	18	13	8	3			
85	100	92	84	77	70	63	56	50	44	38	33	28	22	17	13	9	4		
90	100	92	85	78	71	65	59	53	47	41	36	32	26	22	17	13	9	5	2
95	100	93	86	79	72	66	60	55	49	44	39	35	30	25	21	17	13	10	6
100	100	93	86	80	74	68	62	57	51	47	42	37	33	29	25	21	17	14	10
105	100	93	87	81	75	69	64	58	53	49	44	40	35	31	28	24	20	17	14
110	100	94	87	81	76	70	65	60	55	50	46	42	38	34	30	27	23	20	17
115	100	94	88	82	76	71	66	61	57	52	48	44	40	36	33	29	26	23	20
120	100	94	88	83	77	72	67	62	58	54	49	45	42	38	35	31	28	25	22
125	100	94	88	83	78	73	68	64	59	55	51	47	43	40	37	33	30	27	24
130	100	94	89	83	78	74	69	65	60	56	52	49	45	42	38	35	32	29	27
135	100	94	89	84	79	74	70	65	61	57	53	50	46	43	40	37	34	31	28
140	100	95	89	84	79	75	71	66	62	58	55	51	48	44	41	38	35	33	30

Properties of Dry Air and Mixtures of Air and Water

Vapor at a Barometric Pressure of 29.921 inches of Mercury

Temperature Fahrenheit	Weight of a Cu. Ft. of Dry Air in Pounds	Elastic Force of Vapor in Inches of Mercury	Mixtures of Air Saturated with Vapor				Cubic Feet of Dry Air Warmed One Degree by One B. t. u.
			Elastic Force of Air in the Mixture in Inches of Mercury	Weight of a Cubic Foot of the Mixture in Pounds			
				Air	Vapor	Mixture	
1	2	3	4	5	6	7	8
0	.0864	0.044	29.877	.0863	.000079	.086379	48.5
12	.0842	0.074	29.849	.0840	.000130	.084130	50.1
22	.0824	0.118	29.803	.0821	.000202	.082302	51.1
32	.0807	0.181	29.740	.0802	.000304	.080504	52.0
42	.0791	0.267	29.654	.0784	.000440	.078840	53.2
52	.0766	0.388	29.533	.0766	.000627	.077227	54.0
60	.0764	0.522	29.399	.0751	.000830	.075252	55.0
62	.0761	0.556	29.365	.0747	.000881	.075581	55.2
70	.0750	0.754	29.182	.0731	.001153	.073509	56.2
72	.0747	0.785	29.136	.0727	.001221	.073921	56.3
82	.0733	1.092	28.829	.0706	.001667	.072267	57.2
92	.0720	1.501	28.420	.0684	.002250	.070717	58.4
100	.0710	1.929	27.992	.0664	.002848	.069261	59.1
102	.0707	2.036	27.885	.0659	.002997	.068897	59.5
112	.0694	2.731	27.190	.0631	.003946	.067042	60.6
122	.0682	3.621	26.300	.0599	.005142	.065046	61.7
132	.0671	4.752	25.169	.0564	.006639	.063039	62.5
142	.0660	6.165	23.756	.0524	.008473	.060873	63.7
152	.0649	7.930	21.991	.0477	.010716	.058416	64.7
162	.0638	10.099	19.822	.0423	.013415	.055715	65.8
172	.0628	12.758	17.163	.0360	.016682	.052682	66.9
182	.0618	15.960	13.961	.0288	.020536	.049336	68.0
192	.0609	19.828	10.093	.0205	.025142	.045642	69.0
202	.0600	24.450	5.471	.0109	.030545	.041445	70.0
212	.0591	29.921	0.000	.0000	.036820	.036820	71.1

School House Heaters

The laws in various States cover carefully certain points which must be embodied in the installation of a heating or ventilating system in School Houses.

First. They call for 18 sq. ft. of floor area per pupil.

Second. Not less than 200 cubic feet in room per occupant.

Third. Glass area to be all on one side, and not less than 20 per cent. of the floor area.

Fourth. Ceilings not less than 12 feet in height.

Fifth. Ventilation must be provided to the extent of supplying 30 cubic feet of air per minute per occupant.

This calls for the carrying into the School Room of about three times as much air as would be necessary were the air to act only as a heat carrier, with power enough to offset the normal heat losses in the room. This being true, the air, instead of coming into the room in the neighborhood of 140 degrees, or about 70 degrees above room temperature, it would have to be brought into the room at a temperature of about 90 degrees, or only 20 degrees above room temperature—the greater volume at a lower temperature on account of the legal requirement, instead of the average temperature which would be maintained aside from a legal requirement.

To accomplish this, namely, to bring three times as much air in as would ordinarily be required where no ventilation was figured, and to bring it in at an average of 90 degrees instead of 140, the heater would be called upon to generate almost twice as much heat as where no provisions for ventilation are made.

Therefore, if the system is not to be a mechanical system of heating and ventilation, a heater should be selected having twice as great a capacity as would be used if no special ventilation were required. The pipe sizes will have to be about one-third larger also, owing to the decreased velocity of air existing with such a system.

The square feet of heating surface, given on page 21, may be used in determining the size of heater required, by figuring the average temperature of those surfaces at about 500 degrees, and the average co-efficient of heat transmission for the whole surface at 1.7 B. t. u. per sq. ft. of heating surface per degree difference of temperature per hour.

If a mechanical system is used, however, it may be designed according to the rules and formulae shown on pages 85 to 88.

Asbestos Covering

In order to provide against the possible loss of heat from both the casing of a warm air heater as well as from the warm air pipes, we advise the use of insulating covering.

We advise covering the heater and pipes with some such material, in order to avoid excessive cooling, and at the same time to get the greatest measure of heat from the heater. This covering material is highly recommended, and at the same time has a tendency toward preventing the rusting of pipes and heater casings. This covering can be easily applied, no tools being necessary. Simply wrap it around the heater and pipes, and fasten with wire wound spirally.

Square feet of actual outside surface which must be figured on when ordering Asbestos Board Covering:

900-921-1921	"Perfect"	39.0 sq. ft.
901-922-1922	"	44.5 "
902-924-1924	"	50.5 "
904-926-1926	"	61.0 "
906-928-1928	"	71.0 "
908	"	81.5 "
131	"Perfect"	32.5 sq. ft
135	"	36.5 "
141	"	42.0 "
144	"	47.0 "
148	"	54.0 "
157	"	66.5 "
163	"	79.0 "
171	"	95.0 "
818	"Calorific"	56.0 sq. ft.
821	"	65.5 "
824	"	73.5 "
827	"	82.5 "
830	"	92.0 "
15	"Perfect"	35.0 sq. ft
17	"	43.0 "
19	"	49.5 "
21	"	55.1 "
349	"Perfect"	45.0 sq. ft.
353	"	50.0 "
357	"	60.0 "
363	"	68.0 "
374	"	77.5 "
1028-4028	"Progressive"	26.0 sq. ft.
1032-4032	"	30.0 "
1036-4036	"	34.5 "
1040-4040	"	39.0 "
1044-4044	"	45.0 "
1050-4050	"	55.5 "

Important Facts Regarding Use of Anthracite Coal

It is well to note that the calorific value of a pound of anthracite coal averages 13,500 B.t.u.'s in accordance with the United States Government tests, of which we claim that not more than 9,000 or 9,500 British thermal units are available for heating by means of a high grade warm air heater.

For heating purposes anthracite coal (stove size, or stove and egg size mixed) is best to use in all cases, according to size of heater.

For small heaters use good stove coal.

For medium-sized heaters use good grade stove and small egg coal mixed.

For large-sized heaters use high grade small egg coal.

For moderate seasons, even in large heaters, stove and egg size, mixed, will enable one to better regulate the fire and control it as desired.

Do not use large "furnace coal" under any circumstances. It is too large for practical use.

Note.—In a majority of cases where complaint is made of amount of fuel consumed, it will generally be found that poor grade coal is used, or occasionally large size "furnace" coal, which will not burn well except over a very strong, constant draft.

Dealers giving above advice will enable their customers to secure best results in heating.

The heater capacity, as computed by the **"Richardson"** system of heating and ventilating, must be increased where certain fuels are to be used as follows:

25 per cent. for bituminous coal from Kansas, Oklahoma, Missouri, Kentucky (Western), Illinois, Indiana, Iowa and New Mexico.

33⅓ per cent. for bituminous coal or lignite from Wyoming, Montana, Colorado, North Dakota and Texas.

"Richardson" Heaters are manufactured for the use of hard or soft coal, screenings, pea coal, run-of-mine, coke, gas or wood. One may use fuel at low cost, which may be the most plentiful in your own locality.

Practical Efficiency Test

By the Chicago Board of Health

The Chicago Board of Health has lately made careful search as to the best means of heating and ventilating theatres, schools, auditoriums, etc., which the public are patronizing.

It carried on a most exhaustive test of the **Richardson "Perfect"** Positive Heater (900 Series), the result being most satisfactory, and we recommend to the consideration of the Departments of Education and Health of any city, a careful analysis of this report, which follows:

The principal points desired WERE:

Economy of fuel,
High percentage of efficiency,
Even and proper temperatures,
Durability, and

A construction which, under severe qualifications, would deliver the volume of heat necessary.

By reason of the results of these tests, which were most satisfactory and proved the heater to be highly efficient, the Chicago Board of Health has accepted and is recommending the Richardson line of goods for such purpose.

These tests were carried forward entirely independent of our Company, and the names of those supervising them for the Chicago Board of Health are embodied in the report.

Heaters showing high percentages of efficiency when placed in a mechanical heating and ventilating system, will show the same percentages of efficiency when placed in gravity systems. The construction of the heater, providing, as it does, for a large heating surface in square feet, is adaptable for residence heating as well as the heating of auditoriums, theatres, etc. When these heaters are placed within an exhaust or mechanical system of heating and ventilating, the volume of air delivered is a matter of easy figuring, and the capacity of the heater is just as adaptable to a gravity system within a residence as it is adaptable to a mechanical system. Further than that, the possibilities of delivering large volumes of properly warmed air will provide, in a gravity system within a residence, automatic ventilation.

The tremendous heating power of this heater is conclusively demonstrated by item (37), the total weight of air passing through the heater during the tests. One test showed that the heater supplied heat to 16 tons of air in 4.5 hours, or 3.56 tons of air per hour. Another test showed that the heater supplied heat to 13 tons of air in three hours, or 4⅓ tons per hour. A third test showed that the heater supplied heat to 22 tons of air in 5 hours, or 4.4 tons per hour.

Richardson & Boynton Co.

Summary of Data and Results of Test made by Messrs. Hill, Wilson and Gilespie of the Chicago Board of Health, on a No. 902 Perfect Positive Air Circulating Heat Producer supplied with Air by a 70-inch Bailey Steel Plate Fan.

HEATER DATA

Item		Computation	Unit	
(1)	Date of Test			3/20/14
(2)	Name of Heater			Richardson "Perfect"
(3)	Size of Heater			No. 902
(4)	Grate Area		sq. ft.	2.64
(5)	Total Heating Surface		" "	132
(6)	Heating Surface per sq. ft. of Grate	(5) ÷ (4)	" "	50
(7)	Area of Free Air Passage at Radiator		" "	4.8
(8)	Area of Free Air Passage at Top of Fire Pot		" "	5.17
(9)	Area of Air Outlet from Heater		" "	1.4

FAN DATA

(10)	Size of Fan used, Bailey Steel Plate.		inches	70
(11)	Diam. of Fan Wheel		"	48
(12)	Width of Fan Wheel at Periphery		"	19
(13)	Diam. of Fan Inlet		"	33
(14)	Size of Fan Outlet inside measurement		"	$26\frac{3}{4} \times 26\frac{3}{4}$
(15)	Area of Fan Connection to Heater		sq. ft.	1.4
(16)	Length of Pipe between Fan and Heater		ft.	18.5

TEST DATA AND RESULTS

(17)	Fire started at			10 A.M.
(18)	Duration of Test.		hours	4.5
(19)	Calorific Value of Fuel, Pocahontas Lump Coal		B.T.U.	13868
(20)	Total Fuel Fired (allowing 1 lb. wood = 0.4 coal)		lbs.	127
(21)	Total Ash in Fuel (6.1%)	(20) × 6.1%	"	7.747
(22)	Total Refuse at End of Test		"	43.5
(23)	Total Unburned Fuel	(22)—(21)	"	35.75

COAL ANALYSIS

Vol. Matter	19.42%
Ash	6.10%
Moisture	.30%
Carbon	74.18%
	100.00%

FLUE GAS ANALYSIS

C. O^2	8.2%
O	12.6%
C. O	.2%
N	79.0%
	100.00%

Item	Computation	Unit	
(24) Net Fuel consumed during test	(20)—(23)	lbs.	91.25
(25) Net Fuel consumed per hour	(24) ÷ (18)	"	20.277
(26) Net Fuel consumed per hour per sq. ft. of Grate	(25) ÷ (4)		7.68
(27) Av. Temp. of Air entering Heater		degrees F	38
(28) Av. Temp. of Air leaving Heater		" "	149
(29) Av. Increase in Temp	(28)—(27)	" "	111
(30) Fan Speed		R.P.M.	154
(31) Av. Velocity of Air, Heater outlet Pipe		ft. per min.	1299
(32) Av. Volume of Air leaving Heater per min	(31) × (9)	cu. ft. per min.	1818
(33) Av. Volume of Air leaving Heater per hour	(32) × (60)	cu. ft. per hr.	109080
(34) Av. Volume of Air leaving Heater during Test	(33) × (18)	cu. ft.	490860
(35) Av. Velocity of Air passing over Heater Radiator	(32) ÷ (7)	ft. per min.	378.75
(36) Av. Velocity of Air passing over Heater Fire Pot	(32) ÷ (8)	ft. per min.	351.83
(37) Total weight of Air leaving Heater during Test	(34) × density at (28)	lbs.	31905.9
(38) Volume of Air entering Heater during Test	(37) ÷ density at (27)	cu. ft.	399323
(39) Total Heat utilized in heating the Air	(37) × (29) × .2375	B.T.U.	842571
(40) Total Heat utilized per hour	(39) ÷ (18)	"	187238
(41) Total Heat utilized per hour per sq. ft. of Grate	(40) ÷ (4)	"	70923
(42) Total Heat in Fuel	(24) × (19)	"	1265455
(43) Total Heat in Fuel per hour	(25) × (19)	"	281212
(44) Total Heat in Fuel per hour per sq. ft. of Grate	(26) × (19)	"	106520
(45) Heat utilized per lb. of Coal consumed	(39) ÷ (24)	"	9236.1
(46) Efficiency of Heater	(41) ÷ (44)	%	66.6

Highest Evaporative Results

From Selected Free-burning and Caking Soft Fuels

From U. S. Geological Survey Bulletin No. 332 and U. S. Bureau of Mines Bulletin No. 23.

State	Test No.	Kind of Fuel	County	B. T. U. per Lb.
Alabama	375	Soft—Caking	Bibb	13,671
Alabama	484	Soft—Free-burning	Jefferson	14,447
Arkansas	293	Soft—Caking	Sebastian	13,705
Arkansas	308	Semi-Anthracite—Caking	Johnson	14,125
Arkansas	340	Lignite	Ouachita	9,549
Georgia	481	Soft—Free-burning	Chattanooga	12,865
Illinois	448	Soft—Free-burning	Williamson	12,920
Illinois	511	Soft Briquets	St. Clair	13,271
Illinois	509	Soft—Caking	Saline	13,621
Indiana	428	Soft—Free-burning	Greene	13,099
Indiana	435	Soft—Caking	Pike	13,545
Indiana	464	Soft Briquets	Parke	11,930
Indian Territory	437	Soft—Free-burning		13,932
Indian Territory	449	Semi-Anthracite		14,682
Kansas	311	Soft—Free-burning	Linn	12,333
Kentucky	434	Soft—Free-burning	Union	14,026
Maryland	490	Soft—Free-burning	Allegany	14,515
Maryland	518	Soft Briquets	Allegany	14,717
Missouri	319	Soft—Caking	Randolph	11,747
Montana	477	Lignite—Free-burning	Carbon	11,628
New Mexico	392	Soft—Caking	Colfax	13,059
New Mexico	387	Soft—Free-burning	Colfax	12,721
Ohio	483	Soft—Free-burning	Pelmont	13,381
Pennsylvania	473	Soft—Caking	Indiana	14,240
Pennsylvania	499	Soft—Free-burning	Cambria	14,119
Pennsylvania	514	Soft Briquets	Westm'rl'nd.	14,382
Tennessee	409	Soft Briquets	Claiborne	14,092
Tennessee	368	Soft—Free-burning	Campbell	14,008
Tennessee	363	Soft—Caking	Grundy	13,257
Texas	291	Lignite—Free-burning	Wood	11,131
Utah	404	Soft—Free-burning	Summit	12,586
Virginia	482	Anthracite—Free-burning	Montgomery	12,679
Virginia	507	Soft—Caking	Tazewell	14,177
Washington	290	Subbit.—Free-burning	King	11,772
Washington	359	Soft—Free-burning	Kittitas	12,996
West Virginia	305	Soft—Free-burning	Marion	13,964
West Virginia	439	Soft—Caking	Kanawha	13,995
Wyoming	399	Soft—Free-burning	Carbon	12,222
Wyoming	400	Subbit.—Free-burning	Uinta	12,488

The above valuations were obtained at St. Louis Testing Plant from 139 samples of coal. The heating values of the various coals were established by "actually burning one grain of the air-dried coal in oxygen in a Mahler-bomb calorimeter." These values in B. T. Us. give the theoretical thermal value of soft coals for either high or low pressure heating.

Moisture in Fuel

Many combustibles contain large proportions of moisture, and in the process of combustion, the natural moisture contained in the combustible has a lessening or cooling effect on the burning body of fuel, which lessens its efficiency. In other words, large percentages of heat units within the coal are exhausted in ridding the body of coal of a certain amount of moisture.

Wood in its ordinary state contains 20 per cent. of water. The net combustible matter is reduced to 80 per cent. of the amount contained in the same weight of wood perfectly dry, and of necessity the calorific power is reduced in the same proportion. The second effect is, that part of the heat in the residue is consumed uselessly in evaporating the water.

The experiments of Rumford have shown that the heating power of wood varies only with the state of dryness; that is to say, all different kinds of wood in the same state of dryness yield the same amount of heat.

Coke, containing .85 carbon, shows 10970 B.t.u.'s.

Wood, perfectly dry, containing .51 carbon, shows 6582 B.t.u.'s. Wood, in its ordinary state or average state of dryness, contains .20 of water, and shows 5265 B.t.u.'s.

Charcoal from wood, containing .93 carbon, shows 12000 B.t.u.'s.

Weights of Fuel per Cubic Foot

1 cubic foot of anthracite coal weighs approx... 50 lbs.
1 " " " soft " " " 40 "
1 " " " coke weighs aprox..... 28 "

Centigrade to Fahrenheit

If above freezing point, multiply number of degrees by 9, divide product by 5, and add 32 to quotient.

If below freezing point, multiply number of degrees by 9, divide product by 5, and take difference between 32 and quotient.

Fahrenheit to Centigrade

If above zero, multiply difference between number of degrees and 32 by 5, and divide product by 9.

If below zero, add 32 to number of degrees, multiply sum by 5, and divide product by 9.

Proper Temperature of Rooms, Halls, etc.

Rooms in Which the Occupants are Not Actively Engaged

Living rooms, business rooms, court houses, offices, schools	68
Lecture halls and auditoriums	61 to 64
Rooms used only as sleeping rooms	54 " 59
Bath-rooms in dwellings	68 " 72
Sick rooms	72

Rooms in Which the Occupants are Actively Engaged

Workshops, gymnasiums, etc., where the exertion is vigorous	50 " 59
Workshops in which the exertion is not so vigorous	61 " 64

Rooms Generally Occupied by People in Street Dress

Entrance halls, passages, corridors, and vestibules	54 " 59
Churches	50 " 54

Composition and Heat Values of Anthracite Coals

Locality	Fixed Carbon	Volatile	Moisture	Ash	Sulphur	B T U per Lb.
Anthracite						
Pennsylvania,	78.60			14.80	0.40	
" Buckwheat	81.32	3.84	3.88	10.96	0.67	12,200
" Wilkesbarre	76.94	6.42	1.34	15.30		11,801
" Scranton	79.23	3.73	3.33	13.70		12,149
" Scranton	84.46	5.37	0.97	9.20		12,294
" Cross Creek	89.19	1.96	3.62	5.23		13,723
" Lehigh Valley	75.20	7.36	1.44	16.00		12,423
" Lykens Valley	76.94	6.21				15,300
" Lykens Valley	81.00	5.00				15,300
" Wharton	86.40	3.08	3.71	6.22	0.58	15,000
" Buck Mt	82.66	3.95	3.04	9.88	0.46	15,070
" Beaver Meadow	88.94	2.38	1.50	7.11	0.01	
" Lackawanna	87.74	3.91	2.12	6.35	0.12	
Rhode Island	85.00			7.00	0.90	
Arkansas	74.49	14.73	1.52	9.26		13,217
Semi-Anthracite						
Pennsylvania, Loyalsock	83.34	8.10	1.30	6.23	1.03	15,400
" Bernice	82.52	3.56	0.96	3.27	0.24	15,050
" Bernice	89.39	8.56	0.97	9.34	1.04	15,475
" Wilkesbarre	88.90	7.68		3.49		14,199
" Lycoming Creek	71.53	13.84	0.67	13.96	0.03	
Virginia, Natural Coke	75.08	12.44	1.12	11.38	0.47	
Arkansas	74.06	14.93	1.35	9.66		
Indian Territory	73.21	13.65	5.11	8.03	1.18	13,662
Maryland, Easby	83.60	16.40				11 207

Heat Value and Composition of Various Fuels

Name of Combustible	Composition				Calorific Power B. T. U.
	C	H	Volatile Matter	Ash	
Carbon	1.00				14,400
Anthracite Coal	0.90	0.03	0.03	0.01	13,500
Bituminous Coal	0.85	0.05	0.06	0.06	14,400
Lignite	0.70	0.05	0.20	0.05	11,750
Peat	0.55	0.05	0.30	0.10	9,000
Peat 0.30 Water	0.39	0.04	0.50	0.07	7,200
Coke	0.85	0.05		0.10	12,600
Peat—Charcoal	0.82			0.18	9,000
Dry Wood	0.48	0.06	0.05	0.01	7,200
Wood 0.20 Water	0.40	0.05	0.25	0.01	5,400
Wood-Charcoal	0.80		0.04	0.07	10,800
Hydrogen		1.00			62,000
Carbonic Oxide	0.43		0.57		4,320
Illuminating gas	0.62	0.21	0.17		18,000
Gas from blast furnace	0.06	0.02	0.92		1,620

Note — Above information is quoted from standard authorities. Not guaranteed.

Square feet of exposed wall surface in rooms of various sizes

Height of Ceiling	LENGTH IN FEET OF SIDE EXPOSED														
	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11
8	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88
8½	34	38	42	47	51	55	59	64	68	72	76	81	85	89	93
9	36	40	45	49	54	58	63	67	72	76	81	85	90	94	99
9½	38	43	47	52	57	62	66	71	76	81	85	90	95	100	104
10	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110
10½	42	47	52	58	63	68	73	79	84	89	94	100	105	110	115
11	44	49	55	60	66	71	77	82	88	93	99	104	110	115	121
12	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132
Height of Ceiling	11½	12	12½	13	13½	14	14½	15	15½	16	16½	17	17½	18	18½
8	92	96	100	104	108	112	116	120	124	128	132	136	140	144	148
8½	98	102	106	110	114	119	123	127	132	136	140	144	148	153	157
9	103	108	112	117	121	126	130	135	139	144	148	153	157	162	166
9½	109	114	119	123	128	133	138	142	147	152	157	161	166	171	176
10	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185
10½	121	126	131	136	142	147	152	157	163	168	173	178	184	189	194
11	126	132	137	143	148	154	159	165	170	176	181	187	192	198	203
12	138	144	150	156	162	168	174	180	186	192	198	204	210	216	222

In above totals fractions are omitted.

Square feet of exposed glass surface in windows of various sizes

Width of Window Feet	HEIGHT OF WINDOW IN FEET												
	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8
1½	3	4	4½	5½	6	7	7½	8½	9	10	10½	11½	12
2	4	5	6	7	8	9	10	11	12	13	14	15	16
2½	5	6½	7½	9	10	11½	12½	14	15	16½	17½	19	20
3	6	7½	9	10½	12	13½	15	16½	18	19½	21	22½	24
3½	7	9	10½	12½	14	16	17½	19½	21	23	24½	26½	28
4	8	10	12	14	16	18	20	22	24	26	28	30	32
4½	9	11½	13½	16	18	20½	22½	25	27	29½	31½	34	36
5	10	12½	15	17½	20	22½	25	27½	30	32½	35	37½	40
5½	11	14	16½	19½	22	25	27½	30½	33	36	38½	41½	44
6	12	15	18	21	24	27	30	33	36	39	42	45	48
6½	13	16½	19½	23	26	29½	32½	36	39	42½	45½	49	52
7	14	17½	21	24½	28	31½	35	38½	42	45½	49	52½	56
7½	15	19	22½	26½	30	34	37½	41½	45	49	52½	56½	60
8	16	20	24	28	32	36	40	44	48	52	56	60	64

Air in cubic feet cooled by glass and equivalent glass

ONE DEGREE PER HOUR

To be used in connection with Rules, Pages 44-48.

Glass	Air	Glass	Air	Glass	Air	Glass	Air	Glass	Air
10	750	52	3900	94	7050	136	10200	178	13350
11	825	53	3975	95	7125	137	10275	179	13425
12	900	54	4050	96	7200	138	10350	180	13500
13	975	55	4125	97	7275	139	10425	181	13575
14	1050	56	4200	98	7350	140	10500	182	13650
15	1125	57	4275	99	7425	141	10575	183	13725
16	1200	58	4350	100	7500	142	10650	184	13800
17	1275	59	4425	101	7575	143	10725	185	13875
18	1350	60	4500	102	7650	144	10800	186	13950
19	1425	61	4575	103	7725	145	10875	187	14025
20	1500	62	4650	104	7800	146	10950	188	14100
21	1575	63	4725	105	7875	147	11025	189	14175
22	1650	64	4800	106	7950	148	11100	190	14250
23	1725	65	4875	107	8025	149	11175	191	14325
24	1800	66	4950	108	8100	150	11250	192	14400
25	1875	67	5025	109	8175	151	11325	193	14475
26	1950	68	5100	110	8250	152	11400	194	14550
27	2025	69	5175	111	8325	153	11475	195	14625
28	2100	70	5250	112	8400	154	11550	196	14700
29	2175	71	5325	113	8475	155	11625	197	14775
30	2250	72	5400	114	8550	156	11700	198	14850
31	2325	73	5475	115	8625	157	11775	199	14925
32	2400	74	5550	116	8700	158	11850	200	15000
33	2475	75	5625	117	8775	159	11925	201	15075
34	2550	76	5700	118	8850	160	12000	202	15150
35	2625	77	5775	119	8925	161	12075	203	15225
36	2700	78	5850	120	9000	162	12150	204	15300
37	2775	79	5925	121	9075	163	12225	205	15375
38	2850	80	6000	122	9150	164	12300	206	15450
39	2925	81	6075	123	9225	165	12375	207	15525
40	3000	82	6150	124	9300	166	12450	208	15600
41	3075	83	6225	125	9375	167	12525	209	15675
42	3150	84	6300	126	9450	168	12600	210	15750
43	3225	85	6375	127	9525	169	12675	211	15825
44	3300	86	6450	128	9600	170	12750	212	15900
45	3375	87	6525	129	9675	171	12825	213	15975
46	3450	88	6600	130	9750	172	12900	214	16050
47	3525	89	6675	131	9825	173	12975	215	16125
48	3600	90	6750	132	9900	174	13050	216	16200
49	3675	91	6825	133	9975	175	13125	217	16275
50	3750	92	6900	134	10050	176	13200	218	16350
51	3825	93	6975	135	10125	177	13275	219	16425

Table of Cubical Contents.—Ceiling Heights

Room Size.	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
3 x 3	72	77	81	85	90	95	99	108
3 x 3½	84	89	95	99	105	110	115	126
3 x 4	96	102	108	114	120	126	132	144
3 x 4½	108	115	122	128	135	142	148	162
3 x 5	120	128	135	142	150	158	165	180
3 x 5½	132	140	149	156	165	173	181	198
3 x 6	144	153	162	171	180	189	198	216
3½x 3½	98	104	110	116	123	129	134	147
3½x 4	112	119	126	133	140	147	154	168
3½x 4½	126	134	142	149	158	165	173	189
3½x 5	140	149	158	166	175	184	192	210
3½x 5½	154	164	173	182	193	202	211	231
3½x 6	168	179	189	199	210	221	231	252
3½x 6½	182	193	205	216	228	239	250	273
3½x 7	196	208	221	232	245	257	269	294
4 x 4	128	136	144	152	160	168	176	192
4 x 4½	144	153	162	171	180	189	198	216
4 x 5	160	170	180	190	200	210	220	240
4 x 5½	176	187	198	209	220	231	242	264
4 x 6	192	204	216	228	240	252	264	288
4 x 6½	208	221	234	247	260	273	286	312
4 x 7	224	238	252	266	280	294	308	336
4 x 7½	240	255	270	285	300	315	330	360
4 x 8	256	272	288	304	320	336	352	384
4½x 4½	162	172	182	192	203	213	222	243
4½x 5	180	191	203	213	225	236	247	270
4½x 5½	198	210	223	235	248	260	272	297
4½x 6	216	230	243	256	270	284	297	324
4½x 6½	234	249	263	277	293	307	321	351
4½x 7	252	268	284	299	315	331	346	378
4½x 7½	270	287	304	320	338	354	371	405
4½x 8	288	306	324	342	360	378	396	432
4½x 8½	306	325	344	363	383	402	420	459
4½x 9	324	345	365	384	405	425	445	486
5 x 5	200	212	225	237	250	263	275	300
5 x 5½	220	234	248	261	275	289	302	330
5 x 6	240	255	270	285	300	315	330	360
5 x 6½	260	276	293	308	325	341	357	390
5 x 7	280	297	315	332	350	368	385	420
5 x 7½	300	319	338	358	375	394	412	450
5 x 8	320	340	360	380	400	420	440	480
5 x 8½	340	361	383	403	425	446	467	510
5 x 9	360	382	405	427	450	473	495	540
5 x 9½	380	404	428	451	475	499	522	570
5 x 10	400	425	450	475	500	525	550	600
5½x 5½	242	257	272	287	303	318	332	363
5½x 6	264	281	297	313	330	347	363	396
5½x 6½	286	304	322	339	358	375	393	429
5½x 7	308	327	347	365	385	404	423	462
5½x 7½	330	351	371	391	413	433	453	495
5½x 8	352	374	396	418	440	462	484	528
5½x 8½	374	397	421	444	468	491	514	561
5½x 9	396	421	446	470	495	520	544	594
5½x 9½	418	444	470	496	523	549	574	627

Table of Cubical Contents—Continued. Ceiling Heights

Room Size.	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
5½x10	440	468	495	522	550	578	605	660
5½x10½	462	491	520	548	578	606	635	693
5½x11	484	514	545	574	605	635	665	726
6 x 6	288	306	324	342	360	378	396	432
6 x 6½	312	332	351	370	390	410	429	468
6 x 7	336	357	378	399	420	441	462	504
6 x 7½	360	383	405	427	450	473	495	540
6 x 8	384	408	432	456	480	504	528	576
6 x 8½	408	434	459	484	510	536	561	612
6 x 9	432	459	486	513	540	567	594	648
6 x 9½	456	485	513	541	570	599	627	684
6 x10	480	510	540	570	600	630	660	720
6 x10½	504	536	567	598	630	662	693	756
6 x11	528	561	594	627	660	693	726	792
6 x11½	552	587	621	655	690	725	759	828
6 x12	576	612	648	684	720	756	792	864
6½x 6½	338	359	380	401	423	444	464	507
6½x 7	364	387	410	432	455	478	500	546
6½x 7½	390	414	439	463	488	512	536	585
6½x 8	416	442	468	494	520	546	572	624
6½x 8½	442	470	497	524	553	580	607	663
6½x 9	468	497	527	555	585	615	643	702
6½x 9½	494	525	556	586	618	648	679	741
6½x10	520	553	585	617	650	683	715	780
6½x10½	546	580	614	648	683	717	750	819
6½x11	572	608	644	679	715	751	786	858
6½x11½	598	635	673	710	748	785	822	897
6½x12	624	663	702	741	780	819	858	936
6½x12½	650	691	731	771	813	853	893	975
6½x13	676	718	761	802	845	887	929	1014
7 x 7	392	417	441	465	490	515	539	588
7 x 7½	420	446	473	498	525	551	577	630
7 x 8	448	476	504	532	560	588	616	672
7 x 8½	476	506	536	565	595	625	654	714
7 x 9	504	536	567	598	630	662	693	756
7 x 9½	532	565	599	631	665	698	731	798
7 x10	560	595	630	665	700	735	770	840
7 x10½	588	625	662	698	735	772	808	882
7 x11	616	655	693	731	770	809	847	924
7 x11½	644	684	725	764	805	845	885	966
7 x12	672	714	756	798	840	882	924	1008
7 x12½	700	744	788	831	875	919	962	1050
7 x13	728	774	819	864	910	956	1001	1092
7 x13½	756	803	851	897	945	992	1039	1134
7 x14	784	833	882	931	980	1029	1078	1176
7½x 7½	450	478	506	534	563	591	618	675
7½x 8	480	510	540	570	600	630	660	720
7½x 8½	510	542	574	605	638	669	701	765
7½x 9	540	574	608	641	675	709	742	810
7½x 9½	570	606	641	676	713	748	783	855
7½x10	600	638	675	712	750	788	825	900
7½x10½	630	669	709	748	788	827	866	945
7½x11	660	701	743	783	825	866	907	990
7½x11½	690	733	776	819	863	906	948	1035

Table of Cubical Contents—Continued. Ceiling Heights

Room Size.	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
7½x12	720	765	810	855	900	945	990	1080
7½x12½	750	797	844	890	938	984	1031	1125
7½x13	780	829	878	926	975	1024	1072	1170
7½x13½	810	861	911	961	1013	1063	1113	1215
7½x14	840	893	945	997	1050	1103	1155	1260
7½x14½	870	924	979	1033	1088	1142	1196	1305
7½x15	900	956	1013	1068	1125	1181	1237	1350
8 x 8	512	544	576	608	640	672	704	768
8 x 8½	544	578	612	646	680	714	748	816
8 x 9	576	612	648	684	720	756	792	864
8 x 9½	608	646	684	722	760	798	836	912
8 x10	640	680	720	760	800	840	880	960
8 x10½	672	714	756	798	840	882	924	1008
8 x11	704	748	792	836	880	924	968	1056
8 x11½	736	782	828	874	920	966	1012	1104
8 x12	768	816	864	912	960	1008	1056	1152
8 x12½	800	850	900	950	1000	1050	1100	1200
8 x13	832	884	936	988	1040	1092	1144	1248
8 x13½	864	918	672	1026	1080	1134	1188	1296
8 x14	896	952	1008	1064	1120	1176	1232	1344
8 x14½	928	986	1044	1102	1160	1218	1276	1392
8 x15	960	1020	1080	1140	1200	1260	1320	1440
8 x15½	992	1054	1116	1178	1240	1302	1364	1488
8 x16	1024	1088	1152	1216	1280	1344	1408	1536
8½x 8½	578	614	650	686	723	759	794	867
8½x 9	612	650	689	726	765	803	841	918
8½x 9½	646	686	727	767	808	848	888	969
8½x10	680	723	765	807	850	893	935	1020
8½x10½	714	759	803	847	893	937	981	1071
8½x11	748	795	842	888	935	982	1028	1122
8½x11½	782	831	880	928	978	1026	1075	1173
8½x12	816	867	918	969	1020	1071	1122	1224
8½x12½	850	903	956	1009	1063	1116	1168	1275
8½x13	884	939	995	1049	1105	1160	1215	1326
8½x13½	918	975	1033	1090	1148	1205	1262	1377
8½x14	952	1012	1071	1130	1190	1250	1309	1428
8½x14½	986	1048	1109	1170	1233	1294	1355	1479
8½x15	1020	1084	1148	1211	1275	1339	1402	1530
8½x15½	1054	1120	1186	1251	1318	1383	1449	1581
8½x16	1088	1156	1224	1292	1360	1428	1496	1632
8½x16½	1122	1192	1262	1332	1403	1473	1542	1683
8½x17	1156	1228	1301	1372	1445	1517	1589	1734
9 x 9	648	689	729	769	810	851	891	972
9 x 9½	684	727	770	812	855	898	940	1026
9 x10	720	765	810	855	900	945	990	1080
9 x10½	756	803	851	897	945	992	1039	1134
9 x11	792	842	891	940	990	1040	1089	1188
9 x11½	828	880	932	982	1035	1087	1138	1242
9 x12	864	918	972	1026	1080	1134	1188	1296
9 x12½	900	956	1013	1068	1125	1181	1237	1350
9 x13	936	995	1053	1111	1170	1229	1287	1404
9 x13½	972	1033	1094	1154	1215	1276	1336	1458
9 x14	1008	1071	1134	1197	1260	1323	1386	1512
9 x14½	1044	1109	1175	1239	1305	1370	1435	1566

Table of Cubical Contents—Continued. Ceiling Heights

Room Size.	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
9 x 15	1080	1148	1215	1282	1350	1418	1485	1620
9 x 15½	1116	1186	1256	1325	1395	1465	1534	1674
9 x 16	1152	1224	1296	1368	1440	1512	1584	1728
9 x 16½	1188	1262	1337	1410	1485	1559	1633	1782
9 x 17	1224	1301	1377	1453	1530	1607	1683	1836
9 x 17½	1260	1339	1418	1496	1575	1654	1732	1890
9 x 18	1296	1377	1458	1539	1620	1701	1782	1944
9½x 9½	722	767	812	857	903	948	992	1083
9½x 10	760	808	855	902	950	998	1045	1140
9½x 10½	798	848	898	947	998	1047	1097	1197
9½x 11	836	888	940	992	1045	1097	1149	1254
9½x 11½	874	929	983	1038	1093	1147	1201	1311
9½x 12	912	969	1026	1083	1140	1197	1254	1368
9½x 12½	950	1009	1069	1128	1188	1247	1306	1425
9½x 13	988	1050	1111	1173	1235	1297	1358	1482
9½x 13½	1026	1090	1154	1218	1283	1347	1410	1539
9½x 14	1064	1131	1197	1263	1330	1397	1463	1596
9½x 14½	1102	1171	1240	1308	1378	1446	1515	1653
9½x 15	1140	1211	1282	1353	1425	1496	1567	1710
9½x 15½	1178	1252	1325	1398	1473	1546	1619	1767
9½x 16	1216	1292	1368	1444	1520	1596	1672	1824
9½x 16½	1254	1332	1411	1489	1568	1646	1724	1881
9½x 17	1292	1373	1453	1534	1615	1696	1776	1938
9½x 17½	1330	1413	1496	1579	1663	1746	1828	1995
9½x 18	1368	1454	1539	1624	1710	1796	1881	2052
9½x 18½	1406	1494	1582	1669	1758	1845	1933	2109
9½x 19	1444	1534	1625	1714	1805	1895	1985	2166
10 x 10	800	850	900	950	1000	1050	1100	1200
10 x 10½	840	893	945	997	1050	1103	1155	1260
10 x 11	880	935	990	1045	1100	1155	1210	1320
10 x 11½	920	978	1035	1092	1150	1208	1265	1380
10 x 12	960	1020	1080	1140	1200	1260	1320	1440
10 x 12½	1000	1063	1125	1187	1250	1313	1375	1500
10 x 13	1040	1105	1170	1235	1300	1365	1430	1560
10 x 13½	1080	1148	1215	1282	1350	1418	1485	1620
10 x 14	1120	1190	1260	1330	1400	1470	1540	1680
10 x 14½	1160	1233	1305	1377	1450	1523	1595	1740
10 x 15	1200	1275	1350	1425	1500	1575	1650	1800
10 x 15½	1240	1318	1395	1472	1550	1628	1705	1860
10 x 16	1280	1360	1440	1520	1600	1680	1760	1920
10 x 16½	1320	1403	1485	1567	1650	1733	1815	1980
10 x 17	1360	1445	1530	1615	1700	1785	1870	2040
10 x 17½	1400	1488	1575	1662	1750	1838	1925	2100
10 x 18	1440	1530	1620	1710	1800	1890	1980	2160
10 x 18½	1480	1573	1665	1757	1850	1943	2035	2220
10 x 19	1520	1615	1710	1805	1900	1995	2090	2280
10 x 19½	1560	1658	1755	1852	1950	2048	2145	2340
10 x 20	1600	1700	1800	1900	2000	2100	2200	2400
11 x 11	968	1029	1089	1149	1210	1271	1331	1452
11 x 12	1056	1122	1188	1254	1320	1386	1452	1584
11 x 13	1144	1216	1287	1358	1430	1502	1573	1716
11 x 14	1232	1309	1386	1463	1540	1617	1694	1848
11 x 15	1320	1403	1485	1567	1650	1733	1815	1980
11 x 16	1408	1496	1584	1672	1760	1848	1936	2112

Table of Cubical Contents—Continued

CEILING HEIGHTS

Room Size.	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
11 x 17	1496	1590	1683	1776	1870	1964	2057	2244
11 x 18	1584	1683	1782	1881	1980	2079	2178	2376
11 x 19	1672	1777	1881	1986	2090	2195	2299	2508
11 x 20	1760	1870	1980	2090	2200	2310	2420	2640
11 x 21	1848	1964	2079	2194	2310	2426	2541	2772
11 x 22	1936	2057	2178	2299	2420	2541	2662	2904
12 x 12	1152	1224	1296	1368	1440	1512	1584	1728
12 x 13	1248	1326	1404	1482	1560	1638	1716	1872
12 x 14	1344	1428	1512	1596	1680	1764	1848	2016
12 x 15	1440	1530	1620	1710	1800	1890	1980	2160
12 x 16	1536	1632	1728	1824	1920	2016	2112	2304
12 x 17	1632	1734	1836	1938	2040	2142	2244	2448
12 x 18	1728	1836	1944	2052	2160	2268	2376	2592
12 x 19	1824	1938	2052	2166	2280	2394	2508	2736
12 x 20	1920	2040	2160	2280	2400	2520	2640	2880
12 x 21	2016	2142	2268	2394	2520	2646	2772	3024
12 x 22	2112	2244	2376	2508	2640	2772	2904	3168
12 x 23	2208	2346	2484	2622	2760	2898	3036	3312
12 x 24	2304	2448	2592	2736	2880	3024	3168	3456
13 x 13	1352	1437	1521	1605	1690	1775	1859	2028
13 x 14	1456	1547	1638	1729	1820	1911	2002	2184
13 x 15	1560	1658	1755	1852	1950	2048	2145	2340
13 x 16	1664	1768	1872	1976	2080	2184	2288	2496
13 x 17	1768	1879	1989	2099	2210	2321	2431	2652
13 x 18	1872	1989	2106	2223	2340	2457	2574	2808
13 x 19	1976	2100	2223	2346	2470	2594	2717	2964
13 x 20	2080	2210	2340	2470	2600	2730	2860	3120
13 x 21	2184	2321	2457	2593	2730	2867	3003	3276
13 x 22	2288	2431	2574	2717	2860	3003	3146	3432
13 x 23	2392	2542	2691	2840	2990	3140	3289	3588
13 x 24	2496	2652	2808	2964	3120	3276	3432	3744
13 x 25	2600	2763	2925	3087	3250	3413	3575	3900
13 x 26	2704	2873	3042	3211	3380	3549	3718	4056
14 x 14	1568	1666	1764	1862	1960	2058	2156	2352
14 x 15	1680	1785	1890	1995	2100	2205	2310	2520
14 x 16	1792	1904	2016	2128	2240	2352	2464	2688
14 x 17	1904	2023	2142	2261	2380	2499	2618	2856
14 x 18	2016	2142	2268	2394	2520	2646	2772	3024
14 x 19	2128	2261	2394	2527	2660	2793	2926	3192
14 x 20	2240	2380	2520	2660	2800	2940	3080	3360
14 x 21	2352	2499	2646	2793	2940	3087	3234	3528
14 x 22	2464	2618	2772	2926	3080	3234	3388	3696
14 x 23	2576	2737	2898	3059	3220	3381	3542	3864
14 x 24	2688	2856	3024	3192	3360	3528	3696	4032
14 x 25	2800	2975	3150	3325	3500	3675	3850	4200
14 x 26	2912	3094	3276	3458	3640	3822	4004	4368
14 x 27	3024	3213	3402	3591	3780	3969	4158	4536
14 x 28	3136	3332	3528	3724	3920	4116	4312	4704
15 x 15	1800	1913	2025	2137	2250	2363	2475	2700
15 x 16	1920	2040	2160	2280	2400	2520	2640	2880
15 x 17	2040	2168	2295	2422	2550	2678	2805	3060

Table of Cubical Contents—Continued

Room Size.	CEILING HEIGHTS 8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
15 x 18	2160	2295	2430	2565	2700	2835	2970	3240
15 x 19	2280	2423	2565	2707	2850	2993	3135	3420
15 x 20	2400	2550	2700	2850	3000	3150	3300	3600
15 x 21	2520	2678	2835	2992	3150	3308	3465	3780
15 x 22	2640	2805	2970	3135	3300	3465	3630	3960
15 x 23	2760	2933	3105	3277	3450	3623	3795	4140
15 x 24	2880	3060	3240	3420	3600	3780	3960	4320
15 x 25	3000	3188	3375	3562	3750	3938	4125	4500
15 x 26	3120	3315	3510	3705	3900	4095	4290	4680
15 x 27	3240	3443	3645	3847	4050	4253	4455	4860
15 x 28	3360	3570	3780	3990	4200	4410	4620	5040
15 x 29	3480	3698	3915	4132	4350	4568	4785	5220
15 x 30	3600	3825	4050	4275	4500	4725	4950	5400
16 x 16	2048	2176	2304	2432	2560	2688	2816	3072
16 x 17	2176	2312	2448	2584	2720	2856	2992	3264
16 x 18	2304	2448	2592	2736	2880	3024	3168	3456
16 x 19	2432	2584	2736	2888	3040	3192	3344	3648
16 x 20	2560	2720	2880	3040	3200	3360	3520	3840
16 x 21	2688	2856	3024	3192	3360	3528	3696	4032
16 x 22	2816	2992	3168	3344	3520	3696	3872	4224
16 x 23	2944	3128	3312	3496	3680	3864	4048	4416
16 x 24	3072	3264	3456	3648	3840	4032	4224	4608
16 x 25	3200	3400	3600	3800	4000	4200	4400	4800
16 x 26	3328	3536	3744	3952	4160	4368	4576	4992
16 x 27	3456	3672	3888	4104	4320	4536	4752	5184
16 x 28	3584	3808	4032	4256	4480	4704	4928	5376
16 x 29	3712	3944	4176	4408	4640	4872	5104	5568
16 x 30	3840	4080	4320	4560	4800	5040	5280	5760
16 x 31	3968	4216	4464	4712	4960	5208	5456	5952
16 x 32	4096	4352	4608	4864	5120	5376	5632	6144
18 x 18	2592	2754	2916	3078	3240	3402	3564	3888
18 x 20	2880	3060	3240	3420	3600	3780	3960	4320
18 x 22	3168	3366	3564	3762	3960	4158	4356	4752
18 x 24	3456	3672	3888	4104	4320	4536	4752	5184
18 x 26	3744	3978	4212	4446	4680	4914	5148	5616
18 x 28	4032	4284	4536	4788	5040	5292	5544	6048
18 x 30	4320	4590	4860	5130	5400	5670	5940	6480
18 x 32	4608	4896	5184	5472	5760	6048	6336	6912
18 x 34	4896	5202	5508	5814	6120	6426	6732	7344
18 x 36	5184	5508	5832	6156	6480	6804	7128	7776
20 x 20	3200	3400	3600	3800	4000	4200	4400	4800
20 x 22	3520	3740	3960	4180	4400	4620	4840	5280
20 x 24	3840	4080	4320	4560	4800	5040	5280	5760
20 x 26	4160	4420	4680	4940	5200	5460	5720	6240
20 x 28	4480	4760	5040	5320	5600	5880	6160	6720
20 x 30	4800	5100	5400	5700	6000	6300	6600	7200
20 x 32	5120	5440	5760	6080	6400	6720	7040	7680
20 x 34	5440	5780	6120	6460	6800	7140	7480	8160
20 x 36	5760	6120	6480	6840	7200	7560	7920	8640
20 x 38	6080	6460	6840	7220	7600	7980	8360	9120
20 x 40	6400	6800	7200	7600	8000	8400	8800	9600

Area of Circles

Size	Area	Size	Area	Size	Area	Size	Area
1/8	0.0123	10	78.54	30	706.86	65	3318.3
1/4	0.0491	1/2	86.59	31	754.76	66	3421.2
3/8	0.1104	11	95.03	32	804.24	67	3525.6
1/2	0.1963	1/2	103.86	33	855.30	68	3631.6
5/8	0.3067	12	113.09	34	907.92	69	3739.2
3/4	0.4417	1/2	122.71	35	962.11	70	3848.4
7/8	0.6013	13	132.73	36	1017.8	71	3959.2
1	0.7854	1/2	143.13	37	1075.2	72	4071.5
1/8	0.9940	14	153.93	38	1134.1	73	4185.3
1/4	1.227	1/2	165.13	39	1194.5	74	4300.8
3/8	1.484	15	176.71	40	1256.6	75	4417.8
1/2	1.767	1/2	188.69	41	1320.2	76	4536.4
5/8	2.073	16	201.06	42	1385.4	77	4656.0
3/4	2.405	1/2	213.82	43	1452.2	78	4778.3
7/8	2.761	17	226.98	44	1520.5	79	4901.6
2	3.141	1/2	240.52	45	1590.4	80	5026.5
1/4	3.976	18	254.46	46	1661.9	81	5153.0
1/2	4.908	1/2	268.80	47	1734.9	82	5281.0
3/4	5.939	19	283.52	48	1809.5	83	5410.6
3	7.068	1/2	298.64	49	1885.7	84	5541.7
1/4	8.295	20	314.16	50	1963.5	85	5674.5
1/2	9.621	1/2	330.06	51	2042.8	86	5808.8
3/4	11.044	21	346.36	52	2123.7	87	5944.6
4	12.566	1/2	363.05	53	2206.1	88	6082.1
1/2	15.904	22	380.13	54	2290.2	89	6221.1
5	19.635	1/2	397.60	55	2375.8	90	6361.7
1/2	23.758	23	415.47	56	2463.0	91	6503.8
6	28.274	1/2	433.73	57	2551.7	92	6647.6
1/2	33.183	24	452.39	58	2642.0	93	6792.9
7	38.484	1/2	471.43	59	2733.9	94	6939.7
1/2	44.178	25	490.87	60	2827.4	95	7088.2
8	50.265	26	530.93	61	2922.4	96	7238.2
1/2	56.745	27	572.55	62	3019.0	97	7389.8
9	63.617	28	615.75	63	3117.2	98	7542.9
1/2	70.882	29	660.52	64	3216.9	99	7697.7

To find the circumference of a circle when diameter is given, multiply the given diameter by 3.1416. To find the diameter of a circle when circumference is given, multiply the given circumference by.31831.

Metric and English Measures

Measures of Length

Metric			*English*
1	metre	= 39.37	inches
		= 3.28	feet
.3048	metre	= 1	foot
1	centimetre	= .3937	inch
2.54	centimetres	= 1	inch
1	millimetre	= .03937	inch (1/25 inch, nly.
25.4	millimetres	= 1	inch
1	kilometre	= 1093.61	yards

Measures of Surface

1	square metre	= 10.764	square feet
.0929	square metre	= 1	square foot
1	square centimetre	= .155	square inch
6.452	square centimetres	= 1	square inch
1	square millimetre	= .00155	square inch
645.2	square millimetres	= 1	square inch

Measures of Volume

1	cubic metre	= 35.314	cubic feet
.02832	cubic metre	= 1	cubic foot
1	cubic decimetre	= 61.023	cubic inches
		= .0353	cubic foot
28.32	cubic decimetres	= 1	cubic foot
16.387	cubic centimetres	= 1	cubic inch
1	cubic centimetre	= 1	millimetre
		= .061	cubic inch

Measures of Capacity

1	litre—1 cubic decimetre	= 61.023	cubic inches
		= .0353	cubic foot
		= .2202	gallon (Imperial)
		= 2.202	pounds of water at 62 degrees Fahr.
28.317	litres	= 1	cubic foot (6.25 Imperial gallons)
4.543	litres	= 1	gallon (Imperial)
3.785	litres	= 1	gallon (American)

Measures of Weight

Metric			*English*
28.35	grammes	= 1	ounce avoirdupois
1	kilogramme	= 2.2046	pounds
.4536	kilogramme	= 1	pound
1	metric ton	= .9842	ton of 2240 lbs., or
1000	kilogrammes	= 19.68	cwts. or 2204.6 lbs.
1.016	metric tons	=	1 ton of 2240 pounds
1016	kilogrammes		

Miscellaneous

1	gramme per square millimetre	= 1.422	lbs. per square inch
1	kilogramme per square millimetre	= 1422.32	lbs per square inch
1	kilogramme per square centimetre	= 14.223	lbs. per square inch
1.0335	kg. per sq. centimetre	= 14.7	lbs. per square inch
	1 atmosphere		
0.070308	kilogramme per square centimetre	= 1	lb. per square inch

Climatic Temperatures

Lowest and Average Degrees in the U. S.

October 1st to May 1st. All Stated in Fahrenheit

(Compiled from U. S. Weather Bureau Records)

State	City	Lowest	*Av.
Ala.	Mobile	− 1	57.7
	Montgomery	− 5	56.1
Ariz.	Flagstaff	−21	34.8
	Phoenix	22	58.9
Ark.	Fort Smith	−15	49.5
	Little Rock	−12	52.0
Cal.	San Diego	32	57.2
	Independence	10	48.7
Col.	Denver	−29	38.4
	Grand Jct.	−16	39.2
Conn.	Southington	−19	36.3
D. C.	Washington	−15	42.9
Fla.	Jupiter	24	69.8
	Jacksonville	10	60.9
Ga.	Savannah	8	57.2
	Atlanta	− 8	51.4
Idaho.	Boise	−28	39.6
	Lewiston	−18	42.5
Ill.	Chicago	−23	35.9
	Springfield	−22	39.0
Ind.	Indianapolis	−25	40.4
	Evansville	−15	44.1
Iowa.	Sioux City	−31	32.1
	Keokuk	−26	37.6
Kan.	Dodge City	−26	
	Wichita	−22	42.9
Ky.	Louisville	−20	45.0
La.	New Orleans	7	60.5
	Shreveport	− 5	55.7
Me.	Eastport	−21	31.1
	Portland	−17	33.5
Md.	Baltimore	− 7	43.3
Mass.	Boston	−13	37.2
Mich.	Alpena	−27	29.1
	Detroit	−24	35.3
Minn.	Duluth	−41	25.5
	Minneapolis	−33	28.4
Miss.	Meridian	− 6	53.9
	Vicksburg	− 1	56.0
Mo.	Springfield	−29	43.0
	Hannibal	−20	39.7
Mont.	Havre	−55	27.7
	Helena	−42	30.9
Neb.	North Platte	−35	34.6
	Lincoln	−29	35.8
Nev.	Carson City	−22	
	Winnemucca	−28	37.9
N. H.	Concord	−35	33.1
N. J.	Atlantic City	− 7	41.6
N. Y.	Saranac Lake	−38	34.1
	New York Cy.	− 6	40.1
N. M.	Roswell	−14	48.9
	Santa Fe	−13	38.0
N. C.	Hatteras	8	53.3
	Charlotte	− 5	49.8
N. D.	Devil's Lake	−51	18.9
	Bismarck	−44	23.5
Ohio.	Toledo	−16	36.8
	Columbus	−20	39.8
Okla.	Oklahoma	−17	47.1
Ore.	Baker City	−20	34.1
	Portland	− 2	45.4
Pa.	Pittsburgh	−20	40.8
	Philadelphia	− 6	41.8
R. I.	Providence	− 9	37.5
	Block Island	− 4	39.7
S. C.	Charleston	7	56.9
	Columbia	2	53.5
S. D.	Huron	−43	25.9
	Yankton	−32	31.2
Tenn.	Knoxville	−16	47.0
	Memphis	− 9	50.7
Tex.	Corpus Christi	11	62.7
	Fort Worth	− 8	49.5
Utah.	Salt Lake City	−20	39.7
Vt.	Northfield	−32	27.8
Va.	Cape Henry	5	48.6
	Lynchburg	− 5	45.2
Wash.	Seattle	3	44.3
	Spokane	−30	37.0
W.Va.	Parkersburg	−27	41.9
	Elkins	−21	38.8
Wis.	La Crosse	−43	31.2
	Milwaukee	−25	32.4
Wyo.	Cheyenne	−38	33.7
	Lander	−36	29.0

Weights of Galvanized Sheets

Weight per Sq. Ft. in Lbs.

Gauge									
10	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**
5.781	4.531	3.281	2.656	2.156	1.656	1.406	1.156	.9062	.7812

Weight per Sq. Ft. in Ozs.

Gauge									
10	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**
92.5	72.5	52.5	42.5	34.5	26.5	22.5	18.5	14.5	12.5

Weight of Sheets, Pounds

Size of Sheet	Gauge									
	10	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**
24× 72	69	54	39	32	26	20	17	14	11	9
24× 84	81	63	46	37	30	23	20	16	13	11
24× 96	93	73	53	43	35	27	23	19	15	13
24×120	116	91	66	53	43	33	28	23	18	16
26× 72	75	59	43	35	28	22	18	15	12	10
26× 84	88	69	50	40	33	25	21	18	14	12
26× 96	100	79	57	46	37	29	24	20	16	14
26×120	125	98	71	58	47	36	30	25	20	17
28× 72	81	63	46	37	30	23	20	16	13	11
28× 84	94	74	54	43	35	27	23	19	15	13
28× 96	108	85	61	50	40	31	26	22	17	15
28×120	135	106	77	62	50	39	33	27	21	18
30× 72	87	68	49	40	32	25	21	17	14	12
30× 84	101	79	57	46	38	29	25	20	16	14
30× 96	116	91	66	53	43	33	28	23	18	16
30×120	145	113	82	66	54	41	35	29	23	20
36× 72	104	82	59	48	39	30	25	21	16	14
36× 84	121	95	69	55	45	35	30	24	19	16
36× 96	139	109	79	64	52	40	34	28	22	19
36×120	173	136	98	80	65	50	42	35	27	23

Weights of Galvanized Pipe and Elbows

Smoke Pipe—Joints 26 Inches Long

24 Gauge

7 in. Diam. Lock Seam	4 lb. 8 oz.
8 in. Diam. Lock Seam	5 lb. 2 oz.
9 in. Diam. Lock Seam	6 lb. 2 oz.

26 Gauge

7 in. Diam. Lock Seam	3 lb. 9 oz.
8 in. Diam. Lock Seam	4 lb. 3 oz.

Elbows—4 Piece

24 Gauge

7 in. Diam	1 lb. 11 oz.
8 in. Diam	2 lb. 9 oz.
9 in. Diam	3 lb. 8 oz.

26 Gauge

7 in. Diam	1 lb. 8 oz.
8 in. Diam	1 lb. 14 oz.
9 in. Diam	2 lb. 6 oz.

Stock Sizes Heater Pipe Tin

Sheet	Round	Oval
20×23	7	4×9
20×26	8	4×10½
29×29½	9	4×12
20×32½	10	4×14
20×38	12	4×17

Circumferences

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
½	1.5708	6	18.8496	20	62.832
1	3.1416	7	21.9912	22	69.1152
1½	4.7124	8	25.1328	24	75.3984
2	6.2832	9	28.2744	26	81.6816
2½	7.854	10	31.416	28	87.9648
3	9.4248	11	34.5576	30	94.248
3½	10.9956	12	37.6992	32	100.5312
4	12.5664	14	43.9824	34	106.814
4½	14.1372	15	47.124	36	113.098
5	15.708	16	50.2656	38	119.381
5½	17.2788	18	56.5488	40	125.664

3.1416 times the diameter of a circle equals the circumference.
3 1-7 times the diameter is near enough for most practical purposes.
Circumference of a circle times 0.159155 equals radius.
Circumference of a circle times 0.31831 equals diameter.
Diameter of a circle times 0.86 equals side of inscribed equilateral triangle.
Diameter of a circle times 0.7071 equals side of an inscribed square.
Circumference of a circle times 0.225 equals side of an inscribed square.
Circumference of a circle times 0.282 equals side of an equal square.
Diameter of a circle times 0.8862 equals side of an equal square.
Base of a triangle times ½ the altitude equals area.
Multiplying both diameters and .7854 together equals area of an ellipse.

Stock Sizes of Doors—Areas in Square Feet

	2′ 0″	2′ 2″	2′ 4″	2′ 6″	2′ 8″	2′ 10″	3′ 0″	3′ 6″	4′ 0″
6′ 0″	12.	13.	14.	15.	16.	17.	18.	21.	24.
6′ 4″	12.67	13.74	14.77	15.83	16.88	17.94	19.	22.17	25.33
6′ 6″	13.	14.08	15.16	16.25	17.33	18.41	19.5	22.75	26.
6′ 8″	13.33	14.44	15.55	16.67	17.77	18.88	20.	23.33	26.66
6′ 10″	13.67	14.70	15.94	17.08	18.22	19.36	20.5	23.92	27.33
7′ 0″	14.	15.16	16.33	17.5	18.66	19.83	21.	24.5	28.
7′ 6″	15.	16.25	17.50	18.75	20.	21.25	22.5	26.25	30.
8′ 6″	17.	18.41	19.83	21.25	22.66	24.08	25.5	29.75	34.
9′ 0″	18.	19.49	21.	22.5	23.99	25.50	27.	31.5	36.

Outside doors should be considered in all calculations the same as glass surface.

Table of Approximate Velocities of Air in Flues

Outside Temperature 32 Degrees. Flue 1 sq. ft. area.

Excess of Inside Over Outside Temperature, Degrees

Ht. of Flue	10	20	30	40	50	60	70	80	90	100	120	140
5 feet	77	111	136	159	179	199	216	234	250	266	296	325
10 "	109	156	192	226	254	281	306	330	354	376	418	460
15 "	133	192	236	275	312	344	376	405	432	461	513	565
20 "	154	221	273	319	359	398	434	467	500	532	592	650
25 "	173	248	305	357	402	445	485	522	560	595	660	728
30 "	189	271	334	390	440	487	530	572	612	652	725	798
35 "	204	293	360	423	475	527	574	620	662	705	783	862
40 "	218	311	386	452	508	562	612	662	707	753	836	920
45 "	231	332	408	478	538	597	650	700	750	800	887	977
50 "	244	350	432	503	568	630	685	740	790	843	935	1030

Abridged from table in *Metal Worker*, 1905.

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